

New *Fusarium* species and combinations within the *Gibberella fujikuroi* species complex

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Abstract: Ten *Fusarium* species within the *Gibberella fujikuroi* complex are described and illustrated as new species: *F. acutatum* ex *Triticum* sp. (wheat) and *Cajanus* sp., *F. begoniae* ex *Begonia elatior* hybrid, *F. circinatum* ex *Pinus* spp. and its teleomorph *G. circinata*, *F. concentricum* ex *Musa sapientum* (banana) and *Nilaparvata lugens* (Asian brown leaf hopper), *F. denticulatum* ex *Ipomoea batatas* (sweet potato), *F. guttiforme* ex *Ananas comosus* (pineapple), *F. phyllophilum* ex *Dracaena*, *Sansevieria* and *Gasteria* spp., *F. pseudocircinatum* ex *Solanum* sp. as well as *Pinus kesiya* and *Heteropsylla incisa*, *F. pseudonygamai* ex *Pennisetum typhoides* (millet) and *F. ramigenum* ex *Ficus carica* (figs). One variety, *F. sacchari* var. *elongatum* ex *Nerine bowdenii*, *Vallota* sp. and *Haemanthus* sp. is given species rank as *F. bulbicola*. A neotype is designated for *F. lactis*, a pathogen of *Ficus carica*. A key to the described species is provided.

Key Words: Dlaminia, fungi, hyphomycetes, Hypocreales, Liseola, phytopathogens, systematics

INTRODUCTION

Members of the *Gibberella fujikuroi* (Sawada) Wollenw. species complex of *Fusarium* (section *Liseola*) are responsible for many economically important plant diseases, including the well-known gibberellin phytohormone-induced bakanae disease of *Oryza sativa* (Sun and Snyder, 1981). Species within this complex are noted for the production of many toxic secondary metabolites such as fumonisins, moniliformin and beauvericin mycotoxins (Marasas et al., 1984; Gupta et al., 1991; Leslie, 1995). Section *Liseola* is

recognized in most morphologically based classification schemes for *Fusarium*. Wollenweber and Reinking (1935), Booth (1971), Nirenberg (1976), Gerlach and Nirenberg (1982) and Nelson et al. (1983) accepted 6, 2, 10, 10 and 4 species and varieties, respectively, within section *Liseola*. Because section *Liseola* by definition excludes species that produce chlamydospores (Wollenweber and Reinking, 1935), Kwasna et al. (1991) proposed section *Dlaminia* to accommodate four *Liseola*-like chlamydosporous species described since 1985: *F. dlamini* Marasas et al. (1985), *F. nygamai* Burgess & Trimboli (1986), *F. napiforme* Marasas et al. (1987) and *F. beomiforme* Nelson et al. (1987).

Molecular evidence based on phylogenetic analyses of DNA sequences obtained from multiple unlinked loci, however, strongly indicates that sections *Liseola* and *Dlaminia* are nonmonophyletic (O'Donnell and Cigelnik, 1997; O'Donnell et al., 1998). These analyses identified a monophyletic lineage, the *G. fujikuroi* species complex adopted in the present study, which comprises at least 36 phylogenetically distinct species. This lineage includes all *Liseola* and *Dlaminia* fusaria except *F. beomiforme* together with species of *Fusarium* classified in sections *Discolor* (*F. bactriodoides* Wollenweber, 1934), *Lateritium* (*F. denticulatum* Nirenberg & O'Donnell and *Fusarium* sp. NRRL 25346 incorrectly identified as *F. lateritium* Nees: Fr. by Nelson et al., 1995; Clark et al., 1995) and *Elegans* or *Lateritium* (*F. udum* Butler in: Booth, 1971; Gerlach and Nirenberg, 1982; Nelson et al., 1983).

The goal of the present morphological and molecular systematic study is to formally describe ten new species, give one variety species rank and select a neotype for a rediscovered species, *F. lactis* Pirotta & Riboni (1879). In addition, a key is provided to facilitate identification of all described species within the *G. fujikuroi* complex together with one *Fusarium* species that is phylogenetically not a member of this lineage, *F. nisikadoi* Aoki & Nirenberg (Nirenberg and Aoki, 1997). Two species recently described are included in the key, *F. thapsinum* Klittich et al. (Klittich et al., 1997) and *F. globosum* Rheeder et al. (Rheeder et al., 1996).

In order to maintain cultures in the wild-type condition, it is essential to isolate and cultivate strains on a low nutrient medium such as SNA and to store

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them as soon as possible via lyophilization or in liquid nitrogen. Under these conditions it should be possible to identify all described species by morphological methods. The following morphological criteria are important for differentiating species within the *G. fujikuroi* complex: shape of conidia of the aerial mycelium, length and type of conidial chains grown under standardized conditions that include darkness and continuous black light illumination, production of chlamydospores, origin of conidiophores from the substrate vs. the aerial mycelium, degree of conidiophore branching and whether phialides of the aerial conidiophores are monopodialic or polyphialidic. In a few species the shape of sporodochial conidia is important; two species produce coiled sterile hyphae.

MATERIALS AND METHODS

Strains examined are listed in TABLE I. All strains were cultivated at 20°C in plastic petri dishes on potato dextrose agar (PDA; DIFCO, Detroit, Michigan) in the dark for the production of features such as color, odor and growth rate which are of minor diagnostic relevance. Carrot agar (5% v/v freshly pressed carrot juice, 2.3% Oxoid agar No 3; Columbia, Maryland) was used for the mating studies. For microscopic examination strains were transferred to SNA (synthetic low nutrient agar: per 1 L distilled water 1 g KH₂PO₄, 1 g KNO₃, 0.5 g MgSO₄·7H₂O, 0.5 g KCl, 0.2 g dextrose, 0.2 g sucrose, 0.6 mL 1N NaOH, 23 g agar) with a ca 1 × 2 cm piece of sterile filter paper placed on the cooled agar (Nirenberg, 1976). Cultures were incubated for 10–14 da at 20°C either in complete darkness or under permanent black light (Philips TLD 18 W/08; four light bulbs spaced 12 cm apart and 25 cm from the petri dishes; Nirenberg, 1990). Petri dish cultures were viewed under low power on a Zeiss microscope (×100–200) to monitor features of the aerial mycelium. Once points of sporulation were identified, they were mounted on a microscope slide in a drop of sterile water, viewed at ×400 and ×800 on a Zeiss Axiomat photomicroscope where diagnostic morphological features were recorded photographically and measurements were taken. All photomicrographs were taken of colonies grown on SNA in complete darkness unless otherwise stated. Conidial measurements were taken from at least 30 conidia or ascospores and represent minimum and maximum size and mean value with standard deviation. In order to identify species confidently, the conditions outlined above should be followed in detail. It should be noted that the species can be differentiated mainly by features of the aerial mycelium and production of chlamydospores.

Colors are according to Methuen and can be found in alphabetical order in Kornerup and Wanscher (1978, pp. 146–192). Color codes are not given, since their use would imply an accuracy that does not exist in the cultivation of *Fusarium* strains nor in printed color charts.

DESCRIPTION OF SPECIES

1. *Fusarium acutatum* Nirenberg et O'Donnell, sp. nov.

FIGS. 1–5

Coloniae in PDA quasi 4.1 mm per diem crescentes, temperatura 20°C, margine integro. Mycelium aerium roseo-album, laxe lanosum. Color in parte aversa pallide aurantiacus usque aurantiaco-albus. Sclerotia absentia. Initium sporulationis in mycelio aero praecox in capitulis falsis et in guttulis dispersis in agari superficie; sporodochia post 10 dies ad 3 hebdomades formata. Odor non perceptibilis. Conidiophora in mycelio aero prostrata, plerumque idem cum phialides. Phialides in conidiophoris aeriis cylindricae vel ampulliformes, pro parte maxima monopodialicidae, aliquando orificio conidiogenum alterum formantes; phialides ad 20.0 µm longae et 2.5 µm latae; phialides sporodochiales ampulliformes. Conidia e mycelio aero oriunda parva, ovalia vel allantoidea, pro parte maxima 0-septata, aliquando 1-septata; conidia 0-septata: (5.8–)6.1–7.6–9.0 (–11.2) × (2.1–)2.3–2.7–3.1(–3.8) µm. Conidia sporodochialis leviter falcata, cellula apicali acuta, cellula basali pediformi, plerumque 3-septata: (40.0–)44.0–47.0–50.0 (–52.0) × 3.9–4.1–4.2(–4.4) µm. Chlamydosporae binae vel catenatae vel fasciculatae. Holotypi origo geographicæ. India, hospes ignotus. Ex holotypo culturae. NRRL 13309, BBA 69580, FRC 0-1117, CBS 402.97, IMI 376110.

HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average growth rate of 4.1 mm/da at 20°C; colony margin entire. Aerial mycelium pinkish-white; loosely lanose. Pigmentation in reverse light orange to orange-white. Sclerotia absent. Sporulation starting early in the aerial mycelium in false heads and in dispersed drops on the agar surface; sporodochia formed after 10–21 da. Odor not perceptible. Conidiophores of the aerial mycelium prostrate, mostly identical with simple phialides. Phialides of the aerial conidiophores cylindrical to flask-shaped, mostly monopodialic, sometimes forming a second conidiogenous opening; phialides up to 20.0 µm long and 2.5 µm wide; sporodochial phialides flask-shaped. Conidia borne in the aerial mycelium small, oval to allantoid, mostly 0-septate, occasionally 1-septate; 0-septate: (5.8–)6.1–7.6–9.0 (–11.2) × (2.1–)2.3–2.7–3.1(–3.8) µm. Sporodochial conidia falcate, with an acute apical cell and a foot-like basal cell, mostly 3-septate: (40.0–)44.0–47.0–50.0(–52.0) × 3.9–4.1–4.2(–4.4) µm. Chlamydospores formed in pairs, chains and clusters.

TABLE I. Isolates of the *Gibberella fujikuroi* complex studied

Species	Received as	Host/substrate	Geographical origin ^a	BBA #	NRRL #	Strain source ^b
<i>F. acutatum</i>	<i>F. udum</i>	<i>Cajanus cajan</i>	India	63520	25731	BBA
<i>F. acutatum</i>	<i>F. udum</i>	—	India	69553	13308	FRC O-1116
<i>F. acutatum</i> (ex T) ^c	<i>F. udum</i>	—	India	69580	13309	FRC O-1117
<i>F. acutatum</i>	<i>Fusarium</i>	Homoptera	Pakistan	69718	25118	ARSEF 3704
<i>F. acutatum</i>	<i>Fusarium</i>	Homoptera	Pakistan	69719	25119	ARSEF 3707
<i>F. annulatum</i> (ex T)	<i>F. annulatum</i>	<i>Oryza sativa</i>	Vietnam	63629	13614	CBS 258.54
<i>F. anthophilum</i>	<i>F. anthophilum</i>	<i>Hippeastrum</i> hybrid	Germany	62266	25214	BBA (=BBA 8998) ^d
<i>F. anthophilum</i>	<i>F. anthophilum</i>	<i>Euphorbia pulcherrima</i>	Germany	63270	25216	BBA
<i>F. anthophilum</i>	<i>F. anthophilum</i>	<i>Hippeastrum</i> hybrid	New Zealand	64252	25217	BBA
<i>F. bactridioides</i> (ex T)	<i>F. bactridioides</i>	<i>Cronartium conigenum</i>	USA, Arizona	63602	20476	CBS 177.35
<i>F. begoniae</i> (ex T)	<i>F. sacchari</i> var. cf. <i>elongatum</i>	<i>Begonia</i> hybrid	Germany	67781	25300	BBA
<i>F. begoniae</i>	<i>F. sacchari</i> var. cf. <i>elongatum</i>	<i>Begonia</i> hybrid	Germany	69131	25315	BBA
<i>F. brevicutenulatum</i> (ex T)	<i>Fusarium</i>	<i>Striga asiatica</i>	Madagascar	69197	25446	Kroschel
<i>F. brevicutenulatum</i>	<i>Fusarium</i>	<i>Striga asiatica</i>	Madagascar	69198	25447	Kroschel
<i>F. bulbicola</i> (ex T)	<i>F. sacchari</i> var. <i>elongatum</i> (ex T)	<i>Nerine bowdenii</i>	Germany	63628	13618	BBA (=BBA 12293)
<i>F. bulbicola</i>	<i>F. sacchari</i> var. <i>elongatum</i>	<i>Haemanthus</i> hybrid	Germany	63620	25453	BBA (=BBA 8549)
<i>F. bulbicola</i>	<i>F. sacchari</i> var. <i>elongatum</i>	<i>Nerine bowdenii</i>	Germany	63622	25176	BBA (=BBA 10670)
<i>F. bulbicola</i>	<i>F. sacchari</i> var. <i>elongatum</i> (ex T)	<i>Nerine bowdenii</i>	Germany	63628	13618	CBS 220.76
<i>F. circinatum</i> (ex T)	<i>F. subglutinans</i> f.sp. <i>pini</i>	<i>Pinus radiata</i>	USA, California	69720	25331	T. Gordon SL-1
<i>F. circinatum</i>	<i>F. subglutinans</i> f.sp. <i>pini</i>	<i>Pinus taeda</i>	USA, Georgia	69721	25332	T. Gordon FKt867
<i>F. circinatum</i>	<i>F. subglutinans</i> f.sp. <i>pini</i>	<i>Pinus patula</i>	South Africa	69722	25333	T. Gordon SA-0024
<i>F. circinatum</i>	<i>F. subglutinans</i> f.sp. <i>pini</i>	<i>Pinus patula</i>	South Africa	69854	25621	MRC 6209
<i>F. concentricum</i> (ex T)	<i>F. neoceras</i>	<i>Musa sapientum</i>	Costa Rica	64354	25181	BBA
<i>F. concentricum</i>	<i>F. semitectum</i>	<i>Nilaparvata lugens</i>	South Korea	68483	25202	ARSEF 2053

Isolates studied. NRRL 13308 = FRC O-1116 = BBA 69553 = CBS 739.97 = IMI 375327 = DAOM 225121, India, unknown; NRRL 13309 = FRC O-1117 = CBS 402.97 = BBA 69580 = IMI 376110 (ex holotype), India, unknown; NRRL 25118 = ARSEF 3704 = BBA 69718, Pakistan, [Homoptera: Aphididae] on *Triticum* sp.; NRRL 25119 = ARSEF 3707 = BBA 69719, Pakistan, [Homoptera: Aphididae] on *Triticum* sp.; NRRL 25731 = BBA 63520 = CBS 401.97, India, *Cajanus* sp.

Notes. The epithet refers to the acute apical cell of the sporodochial conidia. *Fusarium acutatum* resembles *F. udum* in producing false heads mostly on single phialides or short, conidiophores that rarely

branch in the aerial mycelium and on the substrate. Both species form chlamydospores in chains and clusters, but the apical cells of the sporodochial conidia in *F. udum* are uncinate while they are acute in *F. acutatum*. All other *Fusarium* species that produce false heads only have aerial conidiophores that are much more branched. Although all isolates of *F. acutatum* originated from Asia, a prediction of our biogeographic hypothesis (O'Donnell et al., 1998) is that this species is an African endemic, and like *F. udum*, it appears to have been introduced into India and Pakistan on African hosts such as *Cajanus* (NRRL 25731 = BBA 63520).

TABLE I. Continued

Species	Received as	Host/substrate	Geographical origin ^a	BBA #	NRRL #	Strain source ^b
<i>F. concentricum</i>	<i>F. subglutinans</i>	<i>Musa sapientum</i>	Guatemala	69855	25666	ITEM 807
<i>F. concentricum</i>	<i>F. subglutinans</i>	<i>Musa sapientum</i>	Guatemala	69856	25667	ITEM 817
<i>F. concentricum</i>	<i>F. subglutinans</i>	<i>Musa sapientum</i>	Guatemala	69857	25668	ITEM 818
<i>F. concentricum</i>	<i>F. subglutinans</i>	<i>Musa sapientum</i>	Guatemala	69858	25669	ITEM 819
<i>F. denticulatum</i>	<i>Fusarium</i>	<i>Ipomoea batatas</i>	Cuba	65244	25189	BBA
<i>F. denticulatum</i>	<i>F. lateritium</i>	<i>Ipomoea batatas</i>	USA, N. Carolina	67769	25302	Clark 4785-1
<i>F. denticulatum</i>	<i>F. lateritium</i>	<i>Ipomoea batatas</i>	USA, Louisiana	67770	25316	Clark F89-81
<i>F. denticulatum</i>	<i>F. lateritium</i>	<i>Ipomoea batatas</i>	Brazil	67771	25314	Clark 91-25-1
<i>F. denticulatum</i> (ex T)	<i>F. lateritium</i>	<i>Ipomoea batatas</i>	USA, Louisiana	67772	25311	Clark F89-22
<i>F. dlamini</i>	<i>F. dlamini</i>	soil	South Africa	69046	25442	MRC 3023
<i>F. dlamini</i>	<i>F. dlamini</i>	soil	South Africa	69047	25443	MRC 3024
<i>F. dlamini</i>	<i>F. oxysporum</i>	soil	USA, Maryland	69727	25355	T. Gordon M9-8S
<i>F. dlamini</i> (ex T)	<i>F. dlamini</i>	soil	South Africa	69859	13164	FRC M-1637
<i>F. fujikuroi</i>	<i>F. fujikuroi</i>	<i>Oryza sativa</i>	Taiwan	63122	—	BBA
<i>F. fujikuroi</i>	<i>F. moniliforme</i>	<i>Oryza sativa</i>	Japan	63217	—	Matuo SUF 881
<i>F. fujikuroi</i> (ex T)	<i>F. fujikuroi</i>	<i>Oryza sativa</i>	Taiwan	63630	13620	BBA (=BBA 12428)
<i>F. fujikuroi</i>	<i>F. fujikuroi</i>	<i>Oryza sativa</i>	China	69741	—	Chen F36
<i>F. globosum</i>	<i>Fusarium</i>	<i>Triticum aestivum</i>	Japan	69017	25193	MAFF 237512
<i>F. globosum</i>	<i>Fusarium</i>	<i>Triticum aestivum</i>	Japan	69018	25190	MAFF 237513
<i>F. globosum</i>	<i>Fusarium</i>	<i>Triticum aestivum</i>	Japan	69019	25198	MAFF 237511
<i>F. guttiforme</i> (ex T)	<i>F. subglutinans</i>	<i>Ananas comosus</i>	Brazil	69661	25295	Ventura E248
<i>F. guttiforme</i>	<i>F. subglutinans</i>	<i>Ananas comosus</i>	Brazil	69663	25297	Ventura E/RG 3383
<i>F. guttiforme</i>	<i>F. subglutinans</i>	<i>Ananas comosus</i>	Brazil	69664	25298	Ventura E/RG 3384
<i>F. guttiforme</i>	<i>F. moniliforme</i> var. <i>subglutinans</i>	<i>Ananas comosus</i>	Brazil	69665	25037	ATCC 38067
<i>F. guttiforme</i>	<i>F. subglutinans</i>	<i>Ananas comosus</i>	Brazil	69860	25624	MRC 6784
<i>F. lactis</i> (ex NT)	<i>F. moniliforme</i>	<i>Ficus carica</i>	USA, California	68590	25200	Michailides F41
<i>F. lactis</i>	<i>F. moniliforme</i>	<i>Ficus carica</i>	USA, California	68591	25338	Michailides F13
<i>F. napiforme</i>	<i>F. napiforme</i>	<i>Pennisetum typhoides</i>	South Africa	67629	25196	FRC M-3560
<i>F. napiforme</i>	<i>F. napiforme</i>	<i>Pennisetum typhoides</i>	South Africa	67630	25201	FRC M-3566
<i>F. napiforme</i> (ex T)	<i>F. napiforme</i>	<i>Pennisetum typhoides</i>	South Africa	69861	13604	FRC M-3563
<i>F. nygamai</i>	<i>F. nygamai</i>	<i>Oryza sativa</i>	Morocco	63175	25449	BBA
<i>F. nygamai</i>	<i>Fusarium</i>	<i>Striga hermonthica</i>	Sudan	65861	25450	BBA
<i>F. nygamai</i>	<i>F. oxysporum</i>	<i>Nicotiana tabacum</i>	Greece	—	25596	ATCC 15645
<i>F. nygamai</i> (ex T)	<i>F. nygamai</i>	<i>Sorghum bicolor</i>	Australia	69862	13448	FRC M-1375
<i>F. phyllophilum</i>	<i>F. proliferatum</i> var. <i>minus</i>	<i>Sansevieria dooneri</i>	Germany	63618	25219	BBA (=BBA 7983)

2. *Fusarium begoniae* Nirenberg et O'Donnell, sp. nov.

FIGS. 6-9

Coloniae in PDA quasi 5.6 mm per diem crescentes, temperatura 20 C, margine integro. Mycelium aerium albidum, gossypinum. Color in parte aversa griseo-fulvidus. Sclerotia absentia. Initium sporulationis in mycelio aero praecox, conidia in capitulis falsis producens, sporodochii post unam hebdodem formatis. Odor non perceptibilis. Conidiophora in mycelio aero saepe idem phialides, parce ramosa, prostrata, conidiophora sporodochialia verticillata. Phialides conidiophorum in mycelio aero mono- et polyphalidicae, cylindricaes usque ad 25.0 µm longae, 3.0 µm latae; phialides sporodochiales ampulliformes. Conidia in

mycelio aero ovalia vel allantoidea et obovoidea, plerumque 0-septata, raro 1-septata; 0-septata: (6.5-)7.3-8.5-9.8(-11.8) × (2.0-)2.4-2.9-3.4(-3.8) µm. Conidia sporodochialia gracilia, longe falcata sed fere recta, cellula apicali leviter rostrata et cellula basali pediformi praedita, plerumque 3-septata: (37.0-)42.4-46.7-51.0(-56.0) × (3.5-)3.6-3.8-4.0 µm. Chlamydospores absentes. Holotypi origo geographica. Germania, in *Begonia elatiore* hybrida. Ex holotypo culturae. NRRL 25300, BBA 67781, CBS 403.97, IMI 375315.

HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average growth rate of 5.6 mm/da at 20 C; colony margin entire. Aerial my-

TABLE I. Continued

Species	Received as	Host/substrate	Geographical origin ^a	BBA #	NRRL #	Strain source ^b
<i>F. phyllophilum</i> (ex T)	<i>F. proliferatum</i> var. <i>minus</i>	<i>Dracaena deremensis</i>	Italy	63625 13617	25178 =CBS 216.76	BBA (=BBA 11730)
<i>F. phyllophilum</i>	<i>F. proliferatum</i> var. <i>minus</i>	<i>Gasteria excavata</i>	Germany	63639	25305	BBA (=BBA 11833)
<i>F. proliferatum</i>	<i>F. proliferatum</i>	<i>Cymbidium</i> sp.	Germany	63624 22944	25448 =CBS 217.76	BBA (=BBA 11341)
<i>F. proliferatum</i>	<i>F. proliferatum</i>	<i>Cattleya</i> hybrid	Germany	63634	25307	BBA (=BBA 11345)
<i>F. proliferatum</i>	<i>F. moniliforme</i> var. <i>lactis</i>	<i>Morus alba</i>	Uzbekistan	65640	25207	Hagen HK37
<i>F. proliferatum</i>	<i>Fusarium</i>	<i>Triticum aestivum</i>	Japan	69011	25306	MAFF 236463
<i>F. proliferatum</i>	<i>Fusarium</i>	<i>Triticum aestivum</i>	Japan	69013	25177	MAFF 237651
<i>F. proliferatum</i>	<i>F. proliferatum</i>	<i>Triticum aestivum</i>	Japan	69070	25182	MAFF 236458
<i>F. proliferatum</i>	<i>F. proliferatum</i>	<i>Triticum aestivum</i>	Japan	69071	25175	MAFF 236459
<i>F. proliferatum</i>	<i>F. proliferatum</i>	soil	Argentina	69540	25222	BBA
<i>F. proliferatum</i>	<i>F. proliferatum</i>	soil	Argentina	69541	25223	BBA
<i>F. proliferatum</i>	<i>F. moniliforme</i>	<i>Gossypium</i> sp.	Russia	69589	25320	Levitin N125
<i>F. pseudoanthophilum</i> (ex T)	<i>Fusarium</i>	<i>Zea mays</i>	Zimbabwe	69002	25211	Frank 12-KW20
<i>F. pseudoanthophilum</i>	<i>Fusarium</i>	<i>Zea mays</i>	Zimbabwe	69003	25209	Frank KA18
<i>F. pseudoanthophilum</i>	<i>Fusarium</i>	<i>Zea mays</i>	Zimbabwe	69004	25210	Frank GW24
<i>F. pseudoanthophilum</i>	<i>Fusarium</i>	<i>Zea mays</i>	Zimbabwe	69030	25206	Frank GW23
<i>F. pseudocircinatum</i>	<i>F. subglutinans</i>	Homoptera	Papua, New Guinea	69598	25034	ARSEF 2301
<i>F. pseudocircinatum</i> (ex T)	<i>F. sacchari</i> var. <i>sacchari</i>	<i>Solanum</i> sp.	Ghana	69636	22946	CBS 126.73
<i>F. pseudocircinatum</i>	<i>F. moniliforme</i> var. <i>subglutinans</i>	<i>Pinus kesiya</i>	Philippines	69723	25372	IMI 294599
<i>F. pseudocircinatum</i>	<i>F. bulbigenum</i>	textile	Panama	—	25737	QM 553
<i>F. pseudocircinatum</i>	<i>F. lactis</i>	dead leaves	Panama	70134	25738	QM 612
<i>F. pseudonygamai</i>	<i>F. moniliforme</i>	<i>Pennisetum typhoides</i>	Nigeria	69551	6022	NRRL
<i>F. pseudonygamai</i> (ex T)	<i>F. nygamai</i>	<i>Pennisetum typhoides</i>	Nigeria	69552	13592	FRC M-1166
<i>F. ramigenum</i>	<i>F. moniliforme</i>	<i>Ficus carica</i>	USA, California	68593	25212	Michailides F62
<i>F. ramigenum</i> (ex T)	<i>F. moniliforme</i>	<i>Ficus carica</i>	USA, California	68592	25208	Michailides F50
<i>F. sacchari</i>	<i>F. sacchari</i> var. <i>sacchari</i>	<i>Saccharum officinarum</i>	India	63320	25310	BBA
<i>F. sacchari</i>	<i>F. sacchari</i> var. <i>sacchari</i>	<i>Saccharum officinarum</i>	India	63340	13999	BBA
<i>F. sacchari</i>	<i>F. sacchari</i> var. <i>sacchari</i>	<i>Saccharum officinarum</i>	India	63342	22038	BBA

celium almost white, cottony. Pigmentation in reverse greyish-yellow. Sclerotia absent. Sporulation starting early in the aerial mycelium by producing conidia in false heads; sporodochia appearing after 1 wk. Odor not perceptible. Conidiophores of the aerial mycelium often identical with phialides, sparsely branched, prostrate; sporodochial conidiophores verticillate. Conidiophores of the aerial mycelium bearing mono- and polyphialides, that are cylindrical, up to 25.0 μm long and 3.0 μm wide; sporodochial phialides flask-shaped. Conidia borne in the aerial mycelium oval

to allantoid and obovoid, mostly 0-septate, occasionally 1-septate; 0-septate: (6.5–)7.3–8.5–9.8(–11.8) \times (2.0–)2.4–2.9–3.4(–3.8) μm . Conidia borne in sporodochia slender, long falcate but almost straight, with a slightly beaked apical cell and a footlike basal cell, mostly 3-septate: (37.0–)42.4–46.7–51.0(–56.0) \times (3.5–)3.6–3.8–4.0 μm . Chlamydospores absent.

Isolates studied. NRRL 25300 = BBA 67781 = CBS 403.97 = DAOM 225116 = IMI 375315 (ex holotype), Germany, *Begonia elatior* hybrid; NRRL 25315 = BBA 69131 = CBS 452.97 = IMI 376114, Germany, *Begonia elatior* hybrid.

TABLE I. Continued

Species	Received as	Host/substrate	Geographical origin ^a	BBA #	NRRL #	Strain source ^b
<i>F. sacchari</i>	<i>F. anthophilum</i>	<i>Saccharum officinarum</i>	Papua, New Guinea	69816	—	Chen (IMI 337696)
<i>F. sacchari</i>	<i>F. neoceras</i> (ex T)	<i>Musa sapientum</i>	Honduras	69863	20471	CBS 147.25
<i>F. subglutinans</i>	<i>F. subglutinans</i>	<i>Zea mays</i>	Iran	62275	22034	BBA (=BBA 11157) Leslie 3809
<i>F. subglutinans</i>	<i>F. sacchari</i> var. <i>subglutinans</i>	<i>Zea mays</i>	Germany	63621	20844	BBA (=BBA 10351)
<i>F. subglutinans</i>	<i>F. subglutinans</i>	<i>Zea mays</i>	USA, Illinois	65921	20981	Leslie 990
<i>F. succisae</i>	<i>F. succisae</i>	<i>Succisa pratensis</i>	Germany	63162	25215	BBA
<i>F. succisae</i>	<i>F. succisae</i>	<i>Succisa pratensis</i>	Germany	63627	13613	BBA (=BBA 12287)
<i>F. thapsinum</i>	<i>Fusarium</i> sp. MP-F	<i>Sorghum</i> sp.	Philippines	69581	22007	Leslie 1733
<i>F. thapsinum</i>	<i>Fusarium</i> sp. MP-F	<i>Sorghum</i> sp.	—	69582	22048	Leslie 4092
<i>F. thapsinum</i>	<i>Fusarium</i> sp. MP-F	<i>Sorghum</i> sp.	—	69583	22049	Leslie 4093
<i>F. thapsinum</i>	<i>Fusarium</i> sp. MP-F	<i>Sorghum</i> sp.	USA, Mississippi	69584	22028	Leslie 2942
<i>F. udum</i>	<i>F. udum</i>	<i>Cajanus cajan</i>	India	62451	25194	BBA (=BBA 10725) 22114 =CBS 747.79
<i>F. udum</i>	<i>F. udum</i>	<i>Crotalaria juncea</i>	India	64843	25313	BBA
<i>F. udum</i>	<i>F. udum</i>	<i>Crotalaria juncea</i>	India	65056	25192	BBA
<i>F. udum</i>	<i>F. udum</i>	<i>Cajanus cajan</i>	India	65058	25199	BBA
<i>F. verticillioides</i>	<i>F. verticillioides</i>	<i>Zea mays</i>	Germany	62264	22172	BBA (=BBA 11778)
<i>F. verticillioides</i>	<i>F. verticillioides</i>	<i>Oryza sativa</i>	India	63172	25616	BBA
<i>F. verticillioides</i>	<i>F. moniliforme</i>	<i>Ficus carica</i>	USA, California	68588	—	Michailides F35
<i>F. verticillioides</i>	<i>Fusarium</i>	<i>Stringa asiatica</i>	Niger	69704	—	Abbasher
<i>F. sp.</i>	<i>Fusarium</i>	palm	Venezuela	65668	25204	Samuels 90-215
<i>F. sp.</i>	<i>Fusarium</i>	wood	Venezuela	65676	25195	Samuels 90-248
<i>F. sp.</i>	<i>Fusarium</i>	<i>Triticum aestivum</i>	Japan	69012	25309	MAFF 237650
<i>F. sp.</i>	<i>Fusarium</i>	<i>Oryza sativa</i>	Japan	69021	25303	MAFF 237649
<i>F. sp.</i>	<i>Fusarium</i>	<i>Zea mays</i>	Zimbabwe	69031	25221	Frank 5bCn8
<i>F. sp.</i>	<i>F. subglutinans</i>	<i>Mangifera indica</i>	India	69662	25226	IMI 304063
<i>F. sp.</i>	<i>F. lateritium</i>	<i>Ipomoea batatas</i>	Peru	69725	25346	Clark 91-8-1
<i>F. sp.</i>	<i>F. babinda</i> (T) DAR 70287	soil	Australia	69872	25807	DAR 70287

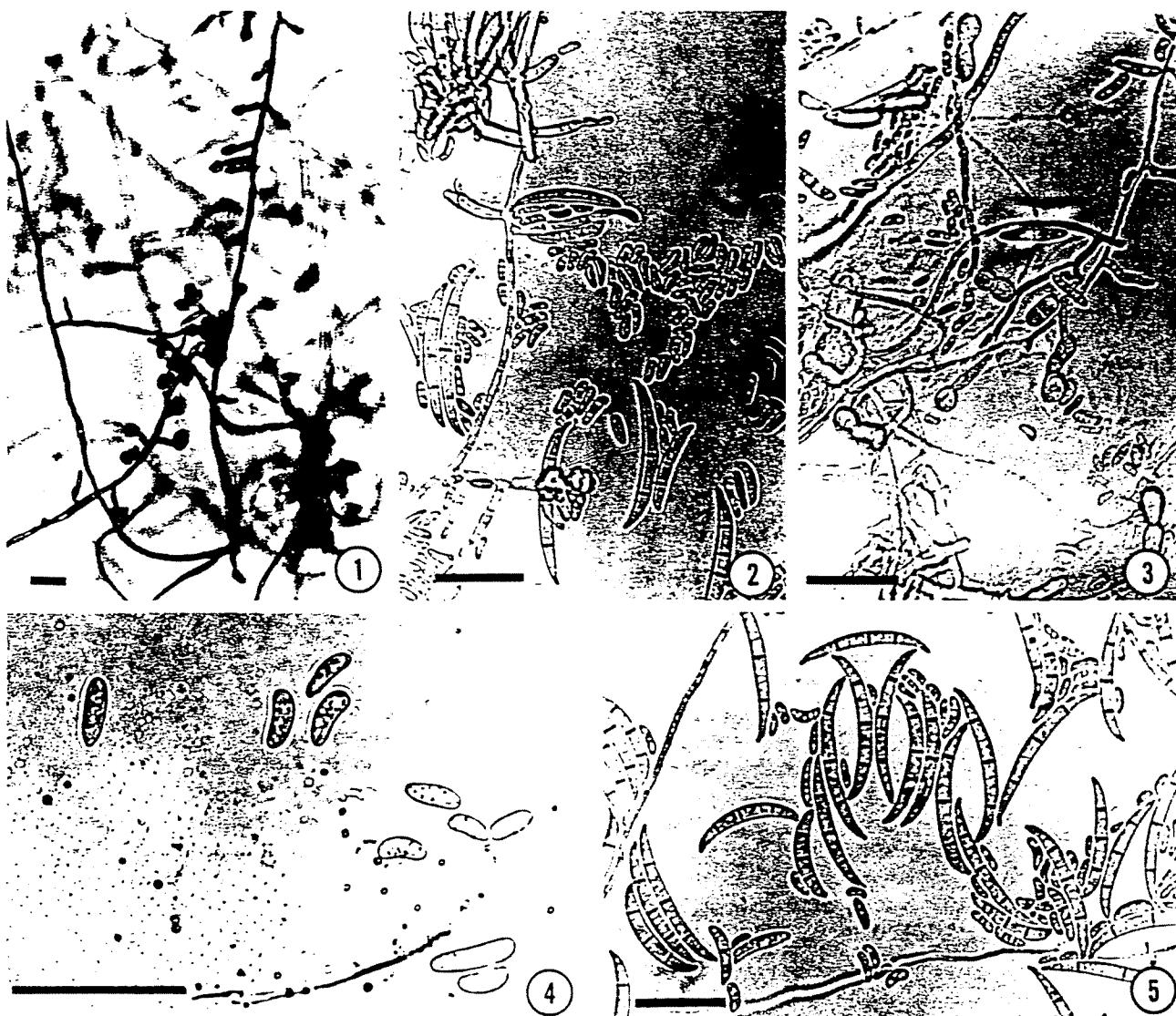
^a Because most of the hosts are agriculturally important plants that are cultivated in different regions of the world, geographic origin of the pathogen may not be the same as its area of endemism (O'Donnell et al., 1998).

^b Strain Source: Abbasher = A. A. Abbasher, B. P. 12404, ICRISAT Sahelian Centre, Niamey, Niger; ATCC = American Type Culture Collection, Rockville, MD; ARSEF = ARS Collection of Entomopathogenic Fungi, Ithaca, NY; BBA = Biologische Bundesanstalt für Land- und Forstwirtschaft, Berlin, Germany; CBS = Centraalbureau voor Schimmelcultures, Baarn, The Netherlands; Chen = F.J. Chen, Institute of Microbiology, Academia Sinica, Beijing, China; Clark = C. Clark, Department of Plant Pathology and Crop Physiology, Louisiana State University, Baton Rouge, LA; DAR = New South Wales Department of Agriculture, Plant Pathology Herbarium, Rydalmore, N. S. W., Australia; FRC = Fusarium Research Center, Pennsylvania State University, University Park, PA; IMI = International Mycological Institute, Egham, England; ITEM = Instituto Tossine e Microtossine, Bari, Italy; Kroschel = J. Kroschel, University of Hohenheim, Stuttgart, Germany; Frank = J. M. Frank, University of Surrey, Guildford, Surrey, England; Leslie = J. F. Leslie, Department of Plant Pathology, Kansas State University, Manhattan, KS; NRRL = Northern Regional Research Laboratory = NCAUR, Peoria, IL; MAFF = Ministry of Agriculture, Forestry and Fisheries, NIAR, Tsukuba, Japan; Michailides = T. J. Michailides, Kearney Agricultural Center, University of California, Parlier, CA; MRC = Medical Research Council, P.O. 19070, Tygerberg, South Africa; QM = Quartermaster Culture Collection housed at NCAUR, Peoria, IL; Samuels = G. J. Samuels, USDA-ARS, BARC-West, Beltsville, MD; T. Gordon = T. R. Gordon, Department of Plant Pathology, University of California, Davis, CA; Ventura = J. A. Ventura, Empresa Capixaba de Pesquisa Agropecuária, Vitória-ES, Brazil.

^c Ex T = ex holotype strain; ex NT = ex neotype strain.

^d BBA numbers in parentheses were published in Nirenberg (1976).

^e The holotype of *F. babinda* DAR 70287 (Summerell et al., 1995) is discordant with the protologue. Morphologically the type and ex T culture (NRRL 25807 = BBA 69872) appear to be *F. anthophilum*, but the phylogenetic evidence indicates that DAR 70287 is a distinct species. The other strains that correspond to the written diagnosis of this species are morphologically and phylogenetically distinct and do not belong to the *Gibberella fujikuroi* complex (O'Donnell et al., 1998; NRRL 25539 = BBA 69788 = Summerell F11165, NRRL 25540 = Summerell F11170 = BBA 69789).



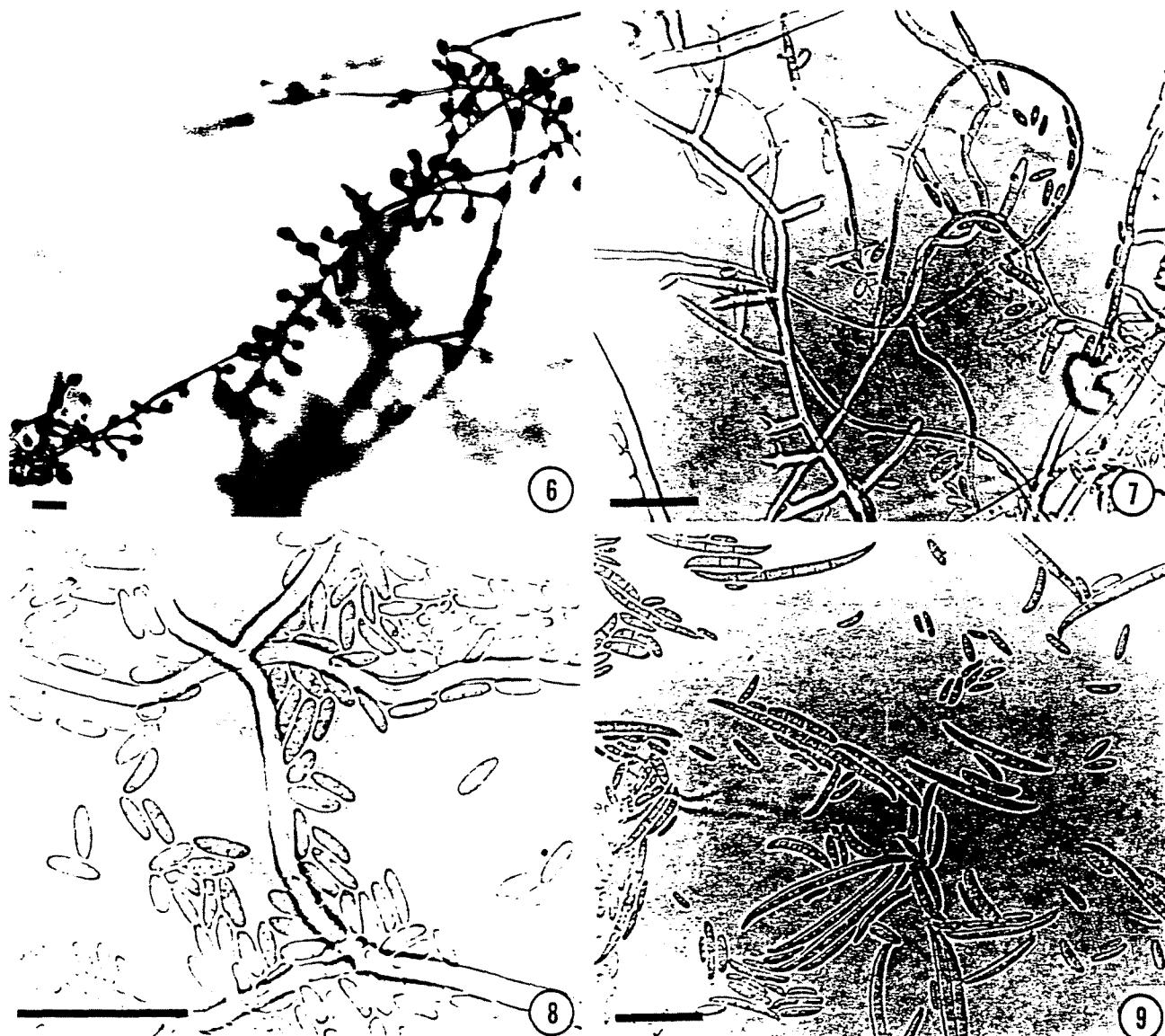
FIGS. 1-5. *Fusarium acutatum*, BBA 69580. 1. Aerial mycelium with simple, prostrate conidiophores producing conidia in false heads. 2. Simple monopodialic conidiophores of the aerial mycelium. 3. Chlamydospores. 4. Allantoid conidia of the aerial mycelium. 5. Sporodochial conidia. Scale bars = 25 μm .

Notes. The epithet is derived from the host *Begonia*. The long sporodochial conidia of *F. begoniae* resemble those of *F. bulbicola*; however, conidiophores of the aerial mycelium are mostly erect and strongly branched in *F. bulbicola* but usually prostrate and rarely branched in *F. begoniae*. The species have different host ranges; *F. bulbicola* occurs on flower bulbs, whereas *F. begoniae* is pathogenic to *Begonia elatior* hybrids. At least one parent of the *Begonia elatior* hybrid is endemic to South America which fits the prediction of our biogeographic hypothesis that *F. begoniae* is an American species (O'Donnell et al., 1998).

3. *Gibberella circinata* Nirenberg et O'Donnell, sp. nov.

FIGS. 15, 16

Perithecia ovoidea vel obpyriformia, ca 325 μm alta, 230 μm lata, non papillata, circum apicem leviter verrucosa sed cetera laevia, solitaria, superficialia vel immersa, non stromatica, atropurpurea in aqua et 3% KOH, rubescens in 100% acido lactic. Paries perithecialis 30–35 μm latus lateraliiter, regiones 2 comprehendens. Regio exterior 15–20 μm lata, cellulis eius in sectione angularibus, 6–15 μm diam., eis cellulis ad interiorem adjacentibus minoribus, parietibus tenuibus provisis et non pigmentiferis, eis cellulis ad exteriorem adjacentibus majoribus, parietibus 1–2 μm crassis et pigmentiferis, regionibus exterioribus et interioribus gradatim inter se commutantibus. Verrucularum cellulae fere globosae, 13–20 μm diam., parietibus 1.5–2.5 μm crassis, plerumque crassioribus in latere exteriore cellulae quaeque quam in latere interiore ubi parietes ca 1 μm crassi sunt. Neque canalis ostiolaris neque paraphyses formantur. Asci cylindrici, 88–100 \times 7.5–8.5 μm , apice annulo refrac-



FIGS. 6-9. *Fusarium begoniae*. 6. Aerial mycelium with simple, prostrate conidiophores producing conidia in false heads. 7. Simple polyphialidic conidiophores of the aerial mycelium. 8. Oval conidia of the aerial mycelium. 9. Sporodochial conidia. FIGS. 6-8 from BBA 69131, 9 from BBA 67781. Scale bars = 25 μm .

tivo non alto proviso. Ascosporeae ellipsoidales vel fusiformes, laeves, hyalinae, septatae, septo medio (9.4)11.1-12.6-14.0(-16.6) \times (4.5)4.7-5.1-5.5(-6.0) μm , septis novis post dimissionem adolescentibus, tum pallide brunneis. Status anamorphicus. *Fusarium circinatum* Nirenberg et O'Donnell. Ex holotypo culturae. BBA 69722, BBA 69720.

HOLOTYPE. Depositus in herb. BPI. ISOTYPE in herb. B

Perithecia ovoidal to obpyriform, ca 325 μm high, 230 μm wide, nonpapillate, slightly warted around the apex but otherwise smooth, solitary, superficial or immersed, nonstromatic, dark purple in water and 3% KOH, becoming red in 100% lactic acid. Perithecial wall 30-35 μm wide laterally, comprising two regions. Outer region 15-20 μm wide, cells angular

in section, 6-15 μm diam with cells toward the interior smaller, thin-walled and nonpigmented and cells toward the exterior larger, with walls 1-2 μm thick and pigmented, the outer and inner regions intergrading. Cells of the warts nearly globose, 13-20 μm diam, walls 1.5-2.5 μm thick, walls tending to be thicker on the "outer" side of each cell than on the inner side, where walls are ca 1 μm thick. Neither ostiolar canal nor periphyses formed. Asci cylindric, 88-100 \times 7.5-8.5 μm , apex with a shallow, refractive ring. Ascospores ellipsoidal to fusiform, smooth, hyaline, septate with septum medium (9.4)11.1-12.6-14.0(-16.6) \times (4.5)4.7-5.1-5.5(-6.0) μm , additional septa developing after discharge, then pale brown.

Notes. The description of the perithecia of *G. cir-*

cinata is based on perithecia formed in culture on 5% carrot agar. Our failure to observe an ostiolar canal and periphyses in these perithecia appears to be an artifact of cultural conditions rather than a true representation of the species as it occurs in nature. Apical paraphyses were observed among asci with developing ascospores. These paraphyses comprised more or less moniliform files of inflated cells, the cells measuring (5)-17-36 × 11-18 µm.

3. ***Fusarium circinatum* Nirenberg et O'Donnell, sp. nov.**

FIGS. 10-16

≡ *Fusarium subglutinans* (Wollenw. et Reinking) Nelson et al. f. sp. *pini* Correll et al., *Plant Dis.* 75: 680. 1991.

Coloniae in PDA quasi 4.7 mm per diem crescentes 20 C. margine integro. Mycelium aerium albidum, in medio substrato tincto griseo-violaceum, pilosum vel lanoso-funiculosum. Color in parte aversa griseus-albidus usque griseus, coloniae centro atroviolaceus. Sclerotia absentia. Initium sporulationis in mycelio aero praecox, conidiis in capitulis falsis aggregatis; sporodochia post 2-3 hebdomades producta. Odor non perceptibilis. Conidiophora in mycelio aero erecta, fortiter ramosa, saepe sympodialiter proliferantia, rami plerumque in 1 vel 2 phialedes terminati, et cum hyphis sterilibus circinatis consociata. Conidiophora sporodochialia verticillata. Phialides in mycelio aero cylindracea, mono- et polyphialidicae, usque ad 30.0 µm longae, 3.0 µm latae. Conidia in mycelio aero plerumque obovoidea vel ovalia ad allantoidea, aliquando fusiformia vel allantoidea, plerumque 0-septata, aliquando 1-septata; 0-septata: (7.0)-8.5-9.7-10.9(-12.0) × (2.5-)2.8-3.2-3.6(-3.9) µm. Conidia sporodochialia gracilia, cylindrica, plerumque 3-septata: (32.0)-33.7-38.2-42.7(-48.0) × (3.2-)3.4-3.6-3.7(-3.8) µm. Chlamydospores absentes. Status teleomorphicus. *Gibberella circinata* Nirenberg et O'Donnell. Holotypi origo geographica. California, USA, in *Pinus radiata*. Ex holotypo culturae. NRRL 25331. BBA 69720. CBS 405.97. IMI 375321. DAOM 225113.

HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average mycelial growth rate of 4.7 mm/da at 20 C; colony margin entire. Aerial mycelium almost white, in the center tinged greyish-violet by the substrate; hairy to lanose-funiculose. Pigmentation in reverse greyish white to grey to dark violet at the center of the colony. Sclerotia absent. Sporulation starting early in the aerial mycelium, conidia aggregated in false heads; sporodochia produced after 2-3 wk. Odor not perceptible. Conidiophores of the aerial mycelium erect, strongly branched, branches terminating mostly in 1 or 2 phialides, often proliferating and associated with coiled sterile hyphae; sporodochial conidiophores verticillately branched. Phialides of the aerial conidiophores cylindrical, mono- and polyphialidic, up to

30.0 µm long and 3.0 µm wide. Conidia borne in the aerial mycelium mostly obovoid, occasionally oval to allantoid, mostly 0-septate, occasionally 1-septate; 0-septata: (7.0)-8.5-9.7-10.9(-12.0) × (2.5-)2.8-3.2-3.6(-3.9) µm. Conidia borne in sporodochia slender, cylindrical, mostly 3-septate: (32.0)-33.7-38.2-42.7 (-48.0) × (3.2-)3.4-3.6-3.7(-3.8) µm. Chlamydospores absent.

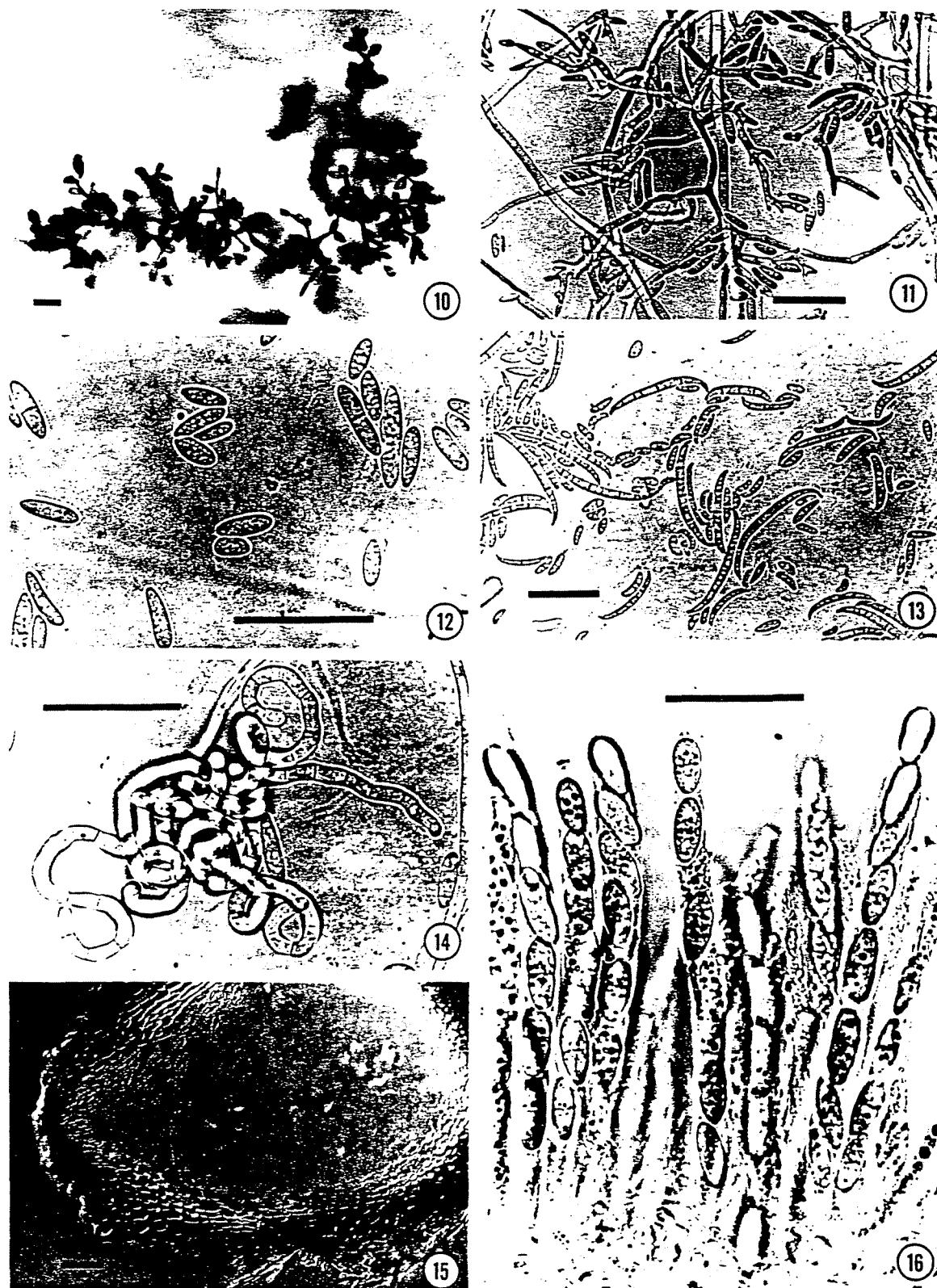
Notes. The epithet refers to the diagnostic coiled hyphae that are produced by this species. Strains of *F. circinatum* were isolated from three species of pine where they had incited the pitch canker disease (Correll et al., 1991). Kuhlman et al. (1978) reported that the pitch canker strains were cross-fertile with *F. subglutinans*; however, inability to reproduce these mating experiments (T. Gordon, pers. comm.; K. O'Donnell, unpubl.) together with the DNA sequence data (O'Donnell et al., 1998) and molecular genetic evidence (Correll et al., 1992; Viljoen et al., 1997) indicate that *F. circinatum* and *F. subglutinans* are phylogenetically distinct species within the American clade of the *G. fujikuroi* complex (O'Donnell et al., 1998). Following the taxonomy of Booth (1971), Kuhlman et al. (1978) referred to the pitch canker isolates as *F. moniliforme* Sheldon var. *subglutinans* Wollenw. et Reinking, but in recent years this pathogen has been called *F. subglutinans* f. sp. *pini* (Correll et al., 1992; Viljoen et al., 1995, 1997). *F. circinatum* is morphologically most similar to an African species, *F. pseudocircinatum*. Both species produce coiled sterile hyphae, but *F. pseudocircinatum* can be distinguished by forming short false chains under continuous black light at 20 C. In contrast to polyphialides of *F. subglutinans*, which have fewer than 3 conidiogenous openings, most polyphialides of *F. circinatum* have more than 3 openings. Conidiophores of *F. circinatum* tend to proliferate strongly, whereas those of *F. subglutinans* are highly branched.

Isolates studied. NRRL 25331 = T. Gordon SL-1 = BBA 69720 = CBS 405.97 = IMI 375321 = DAOM 225113 (*ex holotype*), CA, USA, *Pinus radiata*; NRRL 25332 = T. Gordon FKt867 = BBA 69721, GA, USA, *P. taeda*; NRRL 25333 = T. Gordon SA-0024 = BBA 69722, South Africa, *P. patula*; NRRL 25621 = MRC 6209 = BBA 69854, South Africa, *P. patula*; NRRL 25707 = IMI 211032, NC, USA, *P. caribaea*; NRRL 25708 = IMI 211031, NC, USA, *P. taeda*.

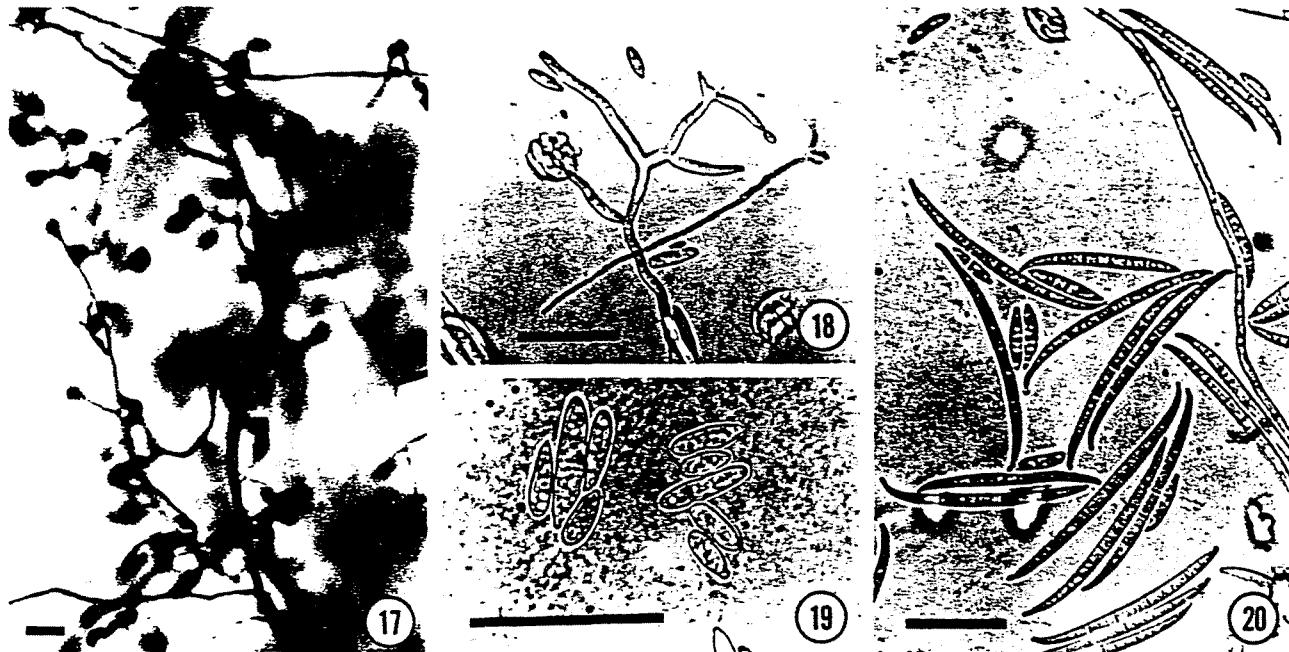
4. ***Fusarium concentricum* Nirenberg et O'Donnell, sp. nov.**

FIGS. 17-20

Coloniae in PDA quasi 4.5 mm per diem crescentes, 20 C, margine integro. Mycelium aerium rubido-album, velutinum usque lanosum. Color in parte aversa zonis concentricis pallide aurantiacis et rubris alternans. Sclerotia absentia. Initium sporulationis praecox in mycelio aero, conidiis



FIGS. 10-16. *Gibberella circinata*. 10. Aerial mycelium with branched conidiophores producing conidia in false heads. 11. Branched polyphialidic conidiophore. 12. Obovoid conidia of the aerial mycelium. 13. Sporodochial conidia. 14. Coiled sterile hyphae. 15. Longitudinal section of perithecioid showing ostiole and two-layered wall. 16. Ascii with ascospores. FIGS. 10-12 from BBA 69720, 13, 14 from BBA 69721, 15, 16 from BBA 69720 × 69722. Scale bars = 25 μm .



Figs. 17-20. *Fusarium concentricum* from BBA 64354. 17. Aerial mycelium with mostly simple, prostrate conidiophores producing conidia in false heads. 18. Simple monopodialic conidiophores of the aerial mycelium. 19. Obovoid to fusoid conidia of the aerial mycelium. 20. Sporodochial conidia. Scale bars = 25 μm .

in capitulis falsis portata, postea sporodochia pallide aurantiaca. Odor non perceptibilis. Conidiophora in mycelio aero plerumque prostrata, simplicia vel uno ramo praedita vel raro verticillum phialidum ferentia; conidiophora sporodochialia verticillata. Phialides in mycelio aero cylindraceae, mono- vel polyphialidicae, usque ad 30.0 μm longae et 3.0 μm latae; phialides sporodochiales ampulliformes. Conidia mycelii aeri obovoidea vel ovalia usque allantoidea, plerumque 0-septata, raro 1-septata; 0-septata: (7.0)-8.3-9.5-10.7(-12.2) \times (2.3)-3.0-3.4-3.9 μm . Conidia sporodochialia gracilia, longa, cellula apicali parum rostrata et cellula basali pediformi praedita, plerumque 3- ad 5-septata; 3-septata: (42.0)-47.3-51.2-55.1(-58.4) \times 3.5-3.7-3.8(-4.0) μm ; 5-septata: (49.0)-53.5-57.4-61.4(-64.8) \times (3.6)-3.7-3.8-4.0 μm . Chlamydospores absentes. Holotypi origo geographicæ. Costa Rica. in *Musa sapientum*. Ex holotypo culturae. NRRL 25181. BBA 64354. CBS 450.97. IMI 375352. DAOM 225146.

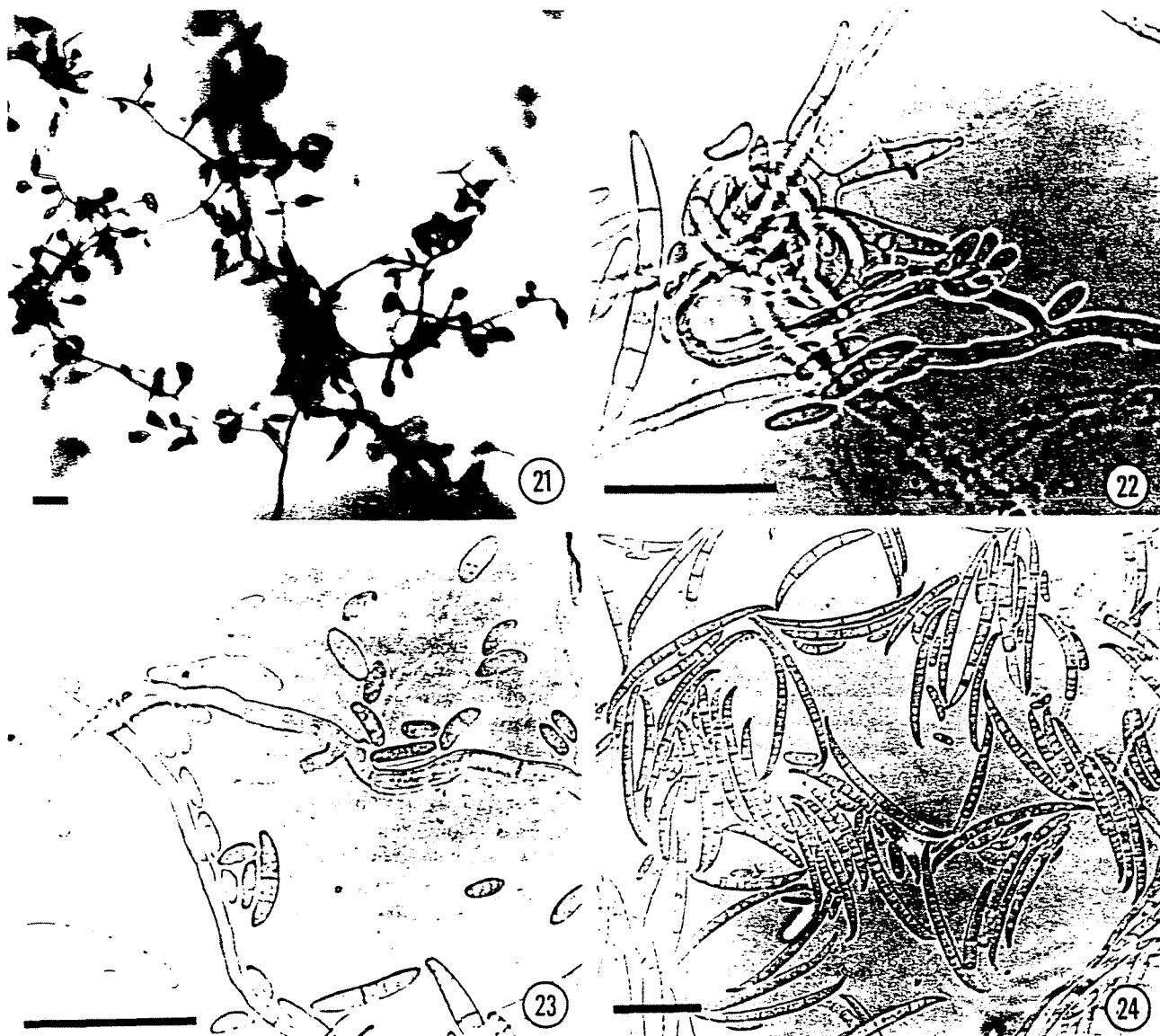
HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average growth rate of 4.5 mm/da at 20 C; colony margin entire. Aerial mycelium reddish-white; velvety to lanose. Pigmentation in reverse consisting of alternating pale orange and reddish-grey concentric rings. Sclerotia absent. Sporulation starting early in the aerial mycelium, conidia borne in false heads; later forming pale orange sporodochia on the surface of the substrate. Odor not perceptible. Conidiophores of the aerial mycelium mainly prostrate, unbranched, with one lateral branch, usually with one phialide, sometimes with a whorl of 4 phialides at the tip; sporodochial conidi-

ophores verticillately branched. Phialides of the aerial conidiophores cylindrical, mono- and polyphialidic, up to 30.0 μm long and 3.0 μm wide; sporodochial phialides flask-shaped. Conidia borne in the aerial mycelium obovoid or oval to allantoid, mostly 0-septate, occasionally 1-septate; 0-septate: (7.0)-8.3-9.5-10.7(-12.2) \times (2.3)-3.0-3.4-3.9 μm . Conidia borne in sporodochia slender, long, with a slightly beaked apical cell and a footlike basal cell, mainly 3- to 5-septate; 3-septate: (42.0)-47.3-51.2-55.1(-58.4) \times 3.5-3.7-3.8(-4.0) μm ; 5-septate: (49.0)-53.5-57.4-61.4(-64.8) \times (3.6)-3.7-3.8-4.0 μm . Chlamydospores absent.

Isolates studied. NRRL 25181 = BBA 64354 = CBS 450.97 = IMI 375352 = DAOM 225146 (*ex holotype*), Costa Rica, *Musa sapientum*; NRRL 25202 = BBA 68483 = ARSEF 2053, Korea, *Nilaparvata lugens* [Homoptera: Delphacidae]; NRRL 25666 = ITEM 807 = BBA 69855, Guatemala, *Musa sapientum*; NRRL 25667 = ITEM 817 = BBA 69856, Guatemala, *Musa sapientum*; NRRL 25668 = ITEM 818 = BBA 69857, Guatemala, *Musa sapientum*; and NRRL 25669 = ITEM 819 = BBA 69858, Guatemala, *Musa sapientum*.

Notes. The epithet refers to the characteristic pigmentation of the colony reverse with alternating pale orange and reddish-grey concentric rings. Although only one isolate of *F. concentricum* was collected in Asia (NRRL 25202 = BBA 68483 *ex Nilaparvata lugens*, the Asian brown plant hopper), a prediction of our biogeographic hypothesis is that *F. concentri-*



FIGS. 21-24. *Fusarium denticulatum* from BBA 67772. 21. Aerial mycelium with mostly simple, prostrate conidiophores producing conidia in false heads. 22. Simple mono- and polyphialidic conidiophores with denticlelike conidiogenous loci. 23. Ovoid, fusoid to allantoid conidia of the aerial mycelium. 24. Sporodochial conidia. Scale bars = 25 μm .

cum was introduced into Central America on its Asian host, *Musa sapientum*. *Fusarium concentricum* resembles *F. guttiforme* and *F. circinatum* in that all three species produce morphologically similar conidia in the aerial mycelium; however, conidiophores of the aerial mycelium are only sparsely branched in *F. concentricum* with only a few polyphialides while in *F. guttiforme* they are strongly branched and in *F. circinatum* strongly proliferating; the latter two species produce abundant polyphialides with many conidiogenous openings. The 4 ITEM isolates of *F. concentricum* were received as *F. subglutinans* from diseased bananas imported into the United States from Guatemala (Vesonder et al., 1995). These authors reported that three of the four isolates tested produced moniliform

min on autoclaved corn. Isolate NRRL 25202 = BBA 68483 was received as a beauvericin-producing strain of *F. semitectum* (Gupta et al., 1991).

**5. *Fusarium denticulatum* Nirenberg et O'Donnell,
sp. nov.**

FIGS. 21-24

Coloniae in PDA 3.0 mm in dies 20 C crescentes; margo lobulata vel integra. Mycelium aerium roseo-album, exiguum, lanosum usque funiculosum. Reversum griseo-aurantium usque brunneo-aurantium, in medio atrocoeruleum. Sclerotia absentia. Sporulatio in mycelio aero post paucos dies capitulis falsis incipitur; deinde parva sporodochia aurantia formantur. Odor non perceptibilis. Conidiophora in mycelio aero prostrata, brevia, saepe ex phialidibus con-

stantia, nonnumquam ramosa; conidiophora sporodochialia verticillata. Cellulae conidiogenae in mycelio aero mono- vel polyphialidicae, ad 20.0 μm longae et 3.0 μm latae; collula polyphialidica saepe denticulata, rectangulariter disposita. Conidia in mycelio aero 0 ad 5-septata, 0 ad 1-septata ovalia vel allantoidea, magis septata fusiformia vel falcata. 0-septata: (5.4)–6.9–8.5–10.1(–12.4) \times (2.0)–2.6–3.0–3.4(–3.8) μm . Conidia sporodochialia modice falcata, cellula apicali rostrata, basilaris pediformi, angusta, plerumque 3- ad 5-septata; 3-septata: (32.0)–37.5–41.2–44.9(–47.6) \times 3.6–3.7–3.9(–4.0) μm . Chlamydospores absentes. Holotypi origo geographica. Louisiana, USA, in *Ipomoea batatas*. Ex holotypo culturae. NRRL 25311, BBA 67772, CBS 407.97, IMI 376115.

HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average mycelial growth rate of 3.0 mm/da at 20 C; colony margin lobed or entire. Aerial mycelium pinkish-white; short, lanose to funiculose. Pigmentation in reverse greyish-orange to brownish-orange with the center blackish-blue. Sclerotia absent. Sporulation starting in the aerial mycelium after a few days in false heads; later small orange sporodochia appear. Odor not perceptible. Conidiophores of the aerial mycelium, prostrate, short, often identical with phialides, sometimes branched; sporodochial conidiophores verticillately branched. Phialides of the aerial conidiophores, mono- or polyphialidic; phialides up to 20.0 μm long \times 3.0 μm wide, polyphialidic openings often denticulate in a rectangular arrangement. Conidia borne in the aerial mycelium 0- to 5-septate, long oval to allantoid when 0- to 1-septate, the higher septate conidia fusiform to falcate; 0-septate conidia: (5.4)–6.9–8.5–10.1(–12.4) \times (2.0)–2.6–3.0–3.4(–3.8) μm . Sporodochial conidia slightly falcate, with a beaked apical cell and a footlike basal cell, slender, usually 3- to 5-septate; 3-septate conidia: (32.0)–37.5–41.2–44.9(–47.6) \times 3.6–3.7–3.9(–4.0) μm . Chlamydospores absent.

Isolates studied. NRRL 25189 = BBA 65244 = CBS 406.97, Cuba, *Ipomoea batatas*; NRRL 25302 = BBA 67769 = CBS 735.97 = IMI 375320 = Clark 4785-1 = DAOM 225112, NC, USA, *I. batatas*; NRRL 25311 = BBA 67772, Clark F89-22 = CBS 407.97 = IMI 376115 (*ex holotype*), LA, USA, *I. batatas*; NRRL 25314 = BBA 67771 = Clark 91-25-1, Brazil, *I. batatas*; NRRL 25316 = BBA 67770 = Clark F89-21, LA, USA, *I. batatas*; NRRL 25345 = Clark 91-82-1, Zambia, *I. batatas*; NRRL 25350 = Clark 91-29-1, Philippines, *I. batatas*; NRRL 25351 = Clark 93-151-1, Indonesia, *I. batatas*; NRRL 25352 = Clark 4785-3, NC, USA, *I. batatas*; NRRL 25465 = Clark 91-02-1, Peru, *I. batatas*.

Notes. The epithet is based on the characteristic denticulate polyphialidic openings produced by this species. All ten strains of *F. denticulatum* were isolated from *Ipomoea batatas*, and eight of these were re-

ceived as *F. lateritium* causing chlorotic leaf distortion of sweet potato (Clark et al., 1995; Nelson et al., 1995). Clark et al.'s (1995) analyses of vegetative compatibility groups within *F. denticulatum* and our phylogenetic evidence (O'Donnell et al., 1998) are consistent with an African origin of this species. These results suggest that sweet potato was infected after it was moved to the Paleotropics by the African species, *F. denticulatum*. Subsequently, *F. denticulatum* became established as a seed-borne pathogen and was distributed over the world with its host. Cultures of *F. denticulatum* resemble *F. lateritium* on PDA by their lobed margin and pigmentation, but *F. lateritium* never produces conidia from polyphialides in the aerial mycelium. The short, rectangular, denticle-like conidiogenous openings of the polyphialides make this species morphologically unique.

6. *Fusarium guttiforme* Nirenberg et O'Donnell, sp. nov.

FIGS. 25–27

Coloniae in PDA quasi 5.2 mm per diem crescentes, 20 C, margine integro. Mycelium aerium albido, postea aliquando substrato transparente griseo-violaceum, humile, lanosum. Color in parte aversa griseo-aurantiacus usque atrovirens. Sclerotia absentia. Initium sporulationis in mycelio aero praecox, conidiis in capitulis falsis aggregatis, sporodochiis non observatis. Odor fructus similis in aliquis isolatis. Conidiophora erecta et prostrata, dense ramosa, rami plerumque in 1 vel 2 phialides terminati. Phialides in mycelio aero cylindricae, monophialidicae sed pro parte maxima polyphialidicae, ad 30.0 μm longae et 3.0 μm latae. Conidia in mycelio aero obovoidea, pro parte maxima 0-septata, aliquando 1-septata; 0-septata: (7.0)–8.5–10.3–12.1(–14.0) \times (2.4)–2.8–3.2–3.7(–4.0) μm . Chlamydospores absentes. Holotypi origo geographica. Brasilia, in *Ananas comosus*. Ex holotypo culturae. NRRL 25295, BBA 69661, CBS 409.97, IMI 376113.

HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average mycelial growth rate of 5.2 mm/da at 20 C; colony margin entire. Aerial mycelium almost white, later sometimes tinged greyish-violet by the substrate; short, lanose. Pigmentation in reverse greyish-orange to dark-violet. Sclerotia absent. Sporulation starting early in the aerial mycelium, conidia aggregated in false heads; sporodochia not observed. Odor faintly fruity in some isolates. Conidiophores of the aerial mycelium erect or prostrate, strongly branched, branches terminating mostly in 1 or 2 phialides. Phialides of the aerial mycelium cylindrical, monophialidic but mostly polyphialidic, up to 30.0 μm long and 3.0 μm wide. Conidia borne in the aerial mycelium ovoid, mostly 0-septate, occasionally 1-septate; 0-septata: (7.0)–8.5–10.3–12.1(–14.0) \times (2.4)–2.8–3.2–3.7(–4.0) μm . Chlamydospores absent.



Figs. 25-27. *Fusarium guttiforme* from BBA 69661. 25. Aerial mycelium with simple and branched, prostrate conidiophores producing conidia in false heads. 26. Simple and branched mono- and polyphialidic conidiophores of the aerial mycelium. 27. Fusoid to obovoid conidia of the aerial mycelium. Scale bars = 25 μm .

Isolates studied. NRRL 22945 = CBS 184.29 = IMI 375350 = DAOM 225144. England. *Ananas comosus*: NRRL 25037 = ATCC 38067 = BBA 69665, Brazil. *A. comosus*: NRRL 25038 = ATCC 42089, Brazil. *A. comosus*; NRRL 25295 = Ventura E248 = BBA 69661 = CBS 409.97 = IMI 376113 (*ex holotype*), Brazil. *A. comosus*; NRRL 25296 = Ventura E/RG 3381, Brazil. *A. comosus*; NRRL 25297 = Ventura E/RG 3383 = BBA 69663, Brazil. *A. comosus*; NRRL 25298 = Ventura E/RG 3384 = BBA 69664 = CBS 410.97, Brazil. *A. comosus*; NRRL 25384 = ATCC 52602, Hawaii. *A. comosus*; NRRL 25624 = MRC 6784 = BBA 69860, Brazil. *A. comosus*.

Notes. The epithet refers to the guttiform or drop-shaped (obovoid) conidia of the aerial mycelium. All nine isolates of *F. guttiforme* were obtained from diseased pineapple (*Ananas comosus*) exhibiting symptoms of fruitlet core rot or basal rot (Rohrbach and Pfeiffer, 1976; Bolkan et al., 1979). Isolates of the pathogen were received as *F. moniliforme* var. *subglutinans* (ATCC 38067, 42089, 52602), *F. sacchari* (Butler) W. Gams var. *sacchari* (CBS 184.29) and *F. subglutinans* (Ventura, pers. comm.; MRC 6784, Viljoen et al., 1995). Both the pathogen and host appear to share the same area of endemism in Brazil. *F. guttiforme* resembles *F. concentricum* and *F. circinatum* in the shape of the conidia of the aerial mycelium, but *F. guttiforme* possesses longer conidia. Unlike *F. concentricum*, *F. guttiforme* produces strongly branched conidiophores with many polyphialides. In this regard, *F. guttiforme* resembles *F. subglutinans*, but the latter species has fewer conidiogenous openings and

a much higher percentage of fusiform, septate conidia in the aerial mycelium. The conidia in *F. sacchari* are of similar shape but smaller in size and are only produced from prostrate conidiophores.

7. *Fusarium phyllophilum* Nirenberg et O'Donnell, sp. nov.

= *F. proliferatum* (Matsushima) Nirenberg ex Gerlach & Nirenb. var. *minus* Nirenberg, *Mitt. Biol. Bundesanst. Land-Forstw. Berlin-Dahlem* 169: 43. 1976.

Coloniae in PDA quasi 4.1 mm per diem crescentes, temperatura 20 C, margine integro. Mycelium aerium albendum, postea aliquando substrato transparente griseo-violaceum, lanoso-funiculosum. Color in parte aversa in aliquis isolatis griseo-albidus, vel griseo-violaceus vel caeruleo-griseus. Sclerotia absentia. Initium sporulationis in mycelio aero post 3 dies, conidia catenis brevibus vel capitulis falsis adhaerentia; sporodochia absentia. Odor fructus similis in aliquis isolatis. Conidiophora in mycelio aero prostrata et ex substrato exorientia, simplicia vel unum ramum vel verticillum ramorum ferentia, cellulis phialides supportantibus saepe inflatis; conidiophora sporodochialia absentia. Phialides in mycelio aero cylindrica, mono- et polyphialidicae, usque ad 40.0 μm longae et 3.0 μm latae. Conidia in mycelio aero plerumque clavata, plerumque 0-septata, aliquando 1 ad 2-septata, 0-septata: (5.6-)7.0-9.4-11.8(-16.0) \times (2.0-)2.4-2.9-3.5(-3.8) μm . Culturae compluribus annis cultivatae nonnulla conidia tenuia falcata, usque 5-septata formantes. Chlamydosporae absentes. Holotypi origo geographic: Italia, in *Dracaena deremens*e. Ex holotypo culturae: NRRL 13617, BBA 63625, CBS 216.76, IMI 375338, DAOM 225132.

HOLOTYPE. Depositus in herb. IMI (202874).

Colonies on PDA showing average mycelial growth rate of 5.8 mm/da at 20 C; colony margin entire. Aerial mycelium white, later tinged greyish-violet by the substrate; lanose to funiculose. Pigmentation in reverse in some isolates greyish-white or greyish-orange to greyish-violet, or greyish-violet to bluish-grey. Sclerotia absent. Sporulation starting after 3 da in the aerial mycelium in short chains and false heads; sporodochia absent. Odor faintly fruity in some isolates. Conidiophores of the aerial mycelium prostrate and erect, unbranched, with one lateral branch or verticillately branched, branches terminating mostly in 1 to 3 phialides, cells beneath the phialides often swollen; sporodochial conidiophores absent. Phialides of the aerial mycelium cylindrical, mono- and polyphialidic, up to 40.0 μm long and 3.0 μm wide. Conidia borne in the aerial mycelium clavate, mostly 0-septate, occasionally 1- to 2-septate; 0-septate: (5.6-)7.0-9.4-11.8(-16.0) \times (2.0-)2.4-2.9-3.5(-3.8) μm . Strains that are cultivated for years produce a few thin, falcate conidia on the agar that are up to 5-septate. Chlamydospores absent.

Isolates studied. NRRL 13296 = FRC M-1219, Germany. *Sansevieria dooneri*. NRRL 13617 = CBS 216.76 = BBA 63625 = IMI 375338 = DAOM 225132, Italy. *Dracaena deremensis* (ex type; dried culture deposited as IMI 202874). NRRL 25053 = CBS 246.61, Germany. *Sansevieria dooneri*. NRRL 25178 = BBA 63625, Italy. *Dracaena deremensis*. NRRL 25219 = BBA 63618, geographic origin unknown. *Sansevieria dooneri*. NRRL 25305 = BBA 63639, Germany. *Gasteria excavata*.

Notes. The epithet refers to the leaf habit of this pathogen. *Fusarium phyllophilum* is not synonymous with *F. moniliforme* var. *minus* Wollenw. s. str. because this variety was described from *Musa* in tropical America and produces conidia in long chains when in culture (Wollenweber, 1931). Wollenweber and Reinking (1935) placed all strains of the *Liseola* section that produced conidial chains but no sporodochia into this variety, and this included also those strains pathogenic to *Sansevieria*. Reports of pathogenicity of *F. moniliforme* var. *minus* on leaves of *Sansevieria* or other plants that have thick leaves actually refer either to *F. phyllophilum* or to only a part of *F. moniliforme* var. *minus* (Gerlach, 1959). *Fusarium phyllophilum* resembles *F. brevicanulatum* (Nirenberg et al., 1998) in producing short chains of conidia and no sporodochia; it can, however, be distinguished from *F. brevicanulatum* by the formation of clavate conidia in the aerial mycelium which cohere in many false heads and short chains in cultures grown in complete darkness, whereas *F. brevicanulatum* produces oval to obovoid conidia in false heads

and short chains only under continuous black light, but not in darkness. The area of endemism of both species appears to be Africa (O'Donnell et al., 1998), but their host ranges do not overlap. *Fusarium phyllophilum* is pathogenic to members of the Dracaenaceae (*Dracaena* and *Sansevieria*) and Asphodelaceae (*Gasteria*) while *F. brevicanulatum* is only known from *Striga asiatica* (Scrophulariaceae).

Fusarium proliferatum var. *proliferatum* was invalid when it was originally proposed (Art. 33.2, Nirenberg, 1976). The name was validated by Gerlach and Nirenberg (1982) and the authorities can be cited as given in the nomenclator above or, more simply, as *F. proliferatum* Gerlach & Nirenberg.

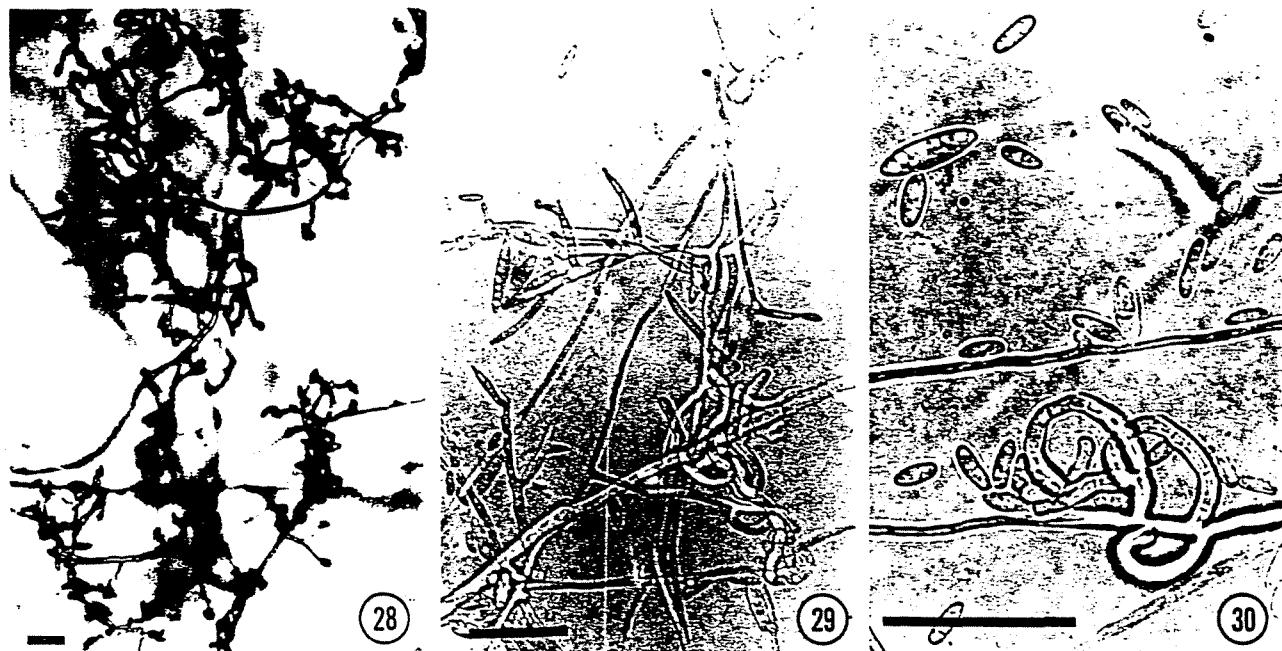
8. *Fusarium pseudocircinatum* O'Donnell et Nirenberg, sp. nov.

FIGS. 28-30

Coloniae in PDA quasi 3.5 mm per diem crescentes, 20 C, margine integro. Mycelium aerium albido, humile, lanoso-funiculosum et plumosum. Color in parte aversa aurantiaco-albidus et coloniae centro atrovirens. Sclerotia absentia. Initium sporulationis praecox in mycelio aero, conidiis in capitulis falsis aggregatis. Catena breves conidiorum imbricatorum sub "luce nigra" continua 20 C formata; sporodochia rara sub "luce nigra" continua post 2 hebdomades solum in agar submersa. Odor non perceptibilis. Conidiophora in mycelio aero prostrata, saepe ex phialibus constituta, aliquando sympodialiter proliferentia; conidiophora sporodochialia verticillata; hyphae steriles circinatae in agari superficie vel in mycelio aero aliquando formatae. Phialides in mycelio aero cylindrica, plerumque monophialidicae sed aliquando polyphialidicae, phialibus usque ad 25.0 μm longis et 3.0 μm latis, phialibus sporodochialibus ampulliformibus. Conidia in mycelio aero ovalia vel obovoidea, plerumque 0-septata, aliquando 1-septata; 0-septata: (5.0-)6.0-7.2-8.3(-10.0) \times (1.9-)2.1-2.5-2.9(-3.2) μm . Conidia sporodochialia modice falcata, cellula apicali leviter rostrata et cellula basali pediformi praedita, plerumque 3-septata: (20.0-)22.4-28.1-33.9(-44.0) \times (2.4-)2.6-2.9-3.3(-3.6) μm . Chlamydospores absentes. Holotypi origo geographicus. Ghana, in *Solanum* sp. Ex holotypi culturae. NRRL 22946, BBA 69636, CBS 126.73, IMI 375316, DAOM 225117.

HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average mycelial growth rate of 3.5 mm/da at 20 C; colony margin entire. Aerial mycelium almost white; short, lanose-funiculose and feathery. Pigmentation in reverse orange-white to dark violet towards the center of the colony. Sclerotia absent. Sporulation starting early in the aerial mycelium, conidia aggregated in false heads; short false chains formed under continuous black light at 20 C; occasionally sporodochia form under continuous black light after 2 wk in the agar only. Odor not perceptible. Conidiophores of the aerial



FIGS. 28-30. *Fusarium pseudocircinatum* from BBA 69636. 28. Aerial mycelium with branched, prostrate conidiophores with false heads and short chains of displaced conidia formed under continuous black light. 29. Branched polyphialidic conidiophores of the aerial mycelium. 30. Coiled sterile hyphae and oval to ovoid conidia of the aerial mycelium. Scale bars = 25 μ m.

mycelium prostrate, often identical with phialides; conidiophores sometimes proliferating sympodially; sporodochial conidiophores verticillately branched; coiled sterile hyphae sometimes appearing on the SNA surface and in the aerial mycelium. Phialides of the aerial conidiophores cylindrical, mostly monopodial, but occasionally polyphialidic; phialides up to 25.0 μ m long and 3.0 μ m wide; sporodochial phialides flask-shaped. Conidia borne in the aerial mycelium oval to ovoid, mostly 0-septate, sometimes 1-septate, 0-septate: (5.0)-6.0-7.2-8.3(-10.0) \times (1.9)-2.1-2.5-2.9(-3.2) μ m. Conidia borne in sporodochia slightly falcate, with a faintly beaked apical cell and a footlike basal cell, mostly 3-septate: (20.0)-22.4-28.1-33.9(-44.0) \times (2.4)-2.6-2.9-3.3(-3.6) μ m. Chlamydospores absent.

Isolates studied. NRRL 22946 = CBS 126.73 = BBA 69636 = CBS 449.97 = IMI 375316 = DAOM 225117 (*ex holotype*), Ghana. *Solanum* sp.; NRRL 25034 = ARSEF 2301 = FRC M-3856 = CBS 455.97 = BBA 69598, Papua New Guinea. *Heteropsylla incisa* [Homoptera: Psyllidae]: NRRL 25372 = IMI 294599 = BBA 69723, Philippines. *Pinus kesiya*: NRRL 25737 = QM 553, Barro Colorado Island, Panama, textile; NRRL 25738 = QM 612 = BBA 70134, Barro Colorado Island, Panama, dead leaves.

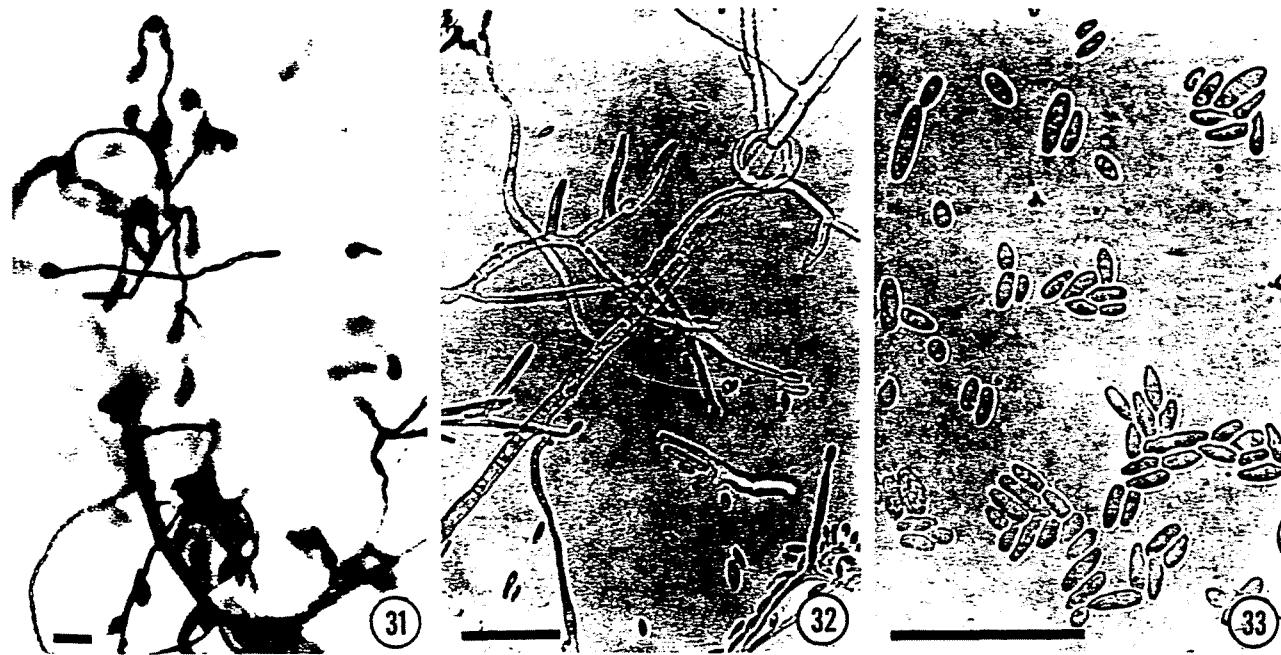
Notes. The five isolates of *F. pseudocircinatum* in our collection exhibit a pantropical distribution (Ghana-Panama-Philippines-Papua New Guinea) consistent with long-distance dispersal. The isolates

were received as *F. sacchari* var. *sacchari* (CBS 126.73), *F. subglutinans* (ARSEF 2301 = FRC M-3856), and *F. moniliforme* var. *subglutinans* (IMI 294599) from three unrelated hosts, and *F. bulbigenum* QM 553 and *F. lactis* QM 612 from textile and dead leaves, respectively. *Fusarium pseudocircinatum* and *F. circinatum* are the only two species of *Fusarium* that produce coiled sterile hyphae on the surface of SNA; however, this feature is interpreted as a morphological convergence since the species are nested in separate clades of the *G. fujikuroi* complex (*F. pseudocircinatum* in Africa, *F. circinatum* in America; O'Donnell et al., 1998). These two species can be distinguished because *F. pseudocircinatum* forms short, false chains under continuous black light at 20 C whereas in *F. circinatum* they only occur in false heads.

9. *Fusarium pseudonygamai* O'Donnell et Nirenberg, sp. nov.

FIGS. 31-33

Coloniae in PDA quasi 4.4 mm per diem crescentes, 20 C. margine integro. Mycelium aerium albido, humile, lanosum usque funiculosum, etiam byssaceum. Color in parte aversa griseo-aurantiacus usque griseo-violaceus, centro atrocoeruleo. Sclerotia absentia. Initium sporulationis in mycelio aero praecox, conidiis in capitulis falsis et catenis brevibus usque longis aggregatis; sporodochia non observata. Odor non perceptibilis. Conidiophora in mycelio aero prostrata, seu ex phialidibus constituata, seu uno vel duabus ramis lateribus praediti, rami plerumque in 1 phialidem



FIGS. 31–33. *Fusarium pseudonygamai*. 31. Aerial mycelium with mostly simple conidiophores producing conidia primarily in false heads, rarely in short or long chains. 32. Simple and singly-branched monopodialic conidiophores. 33. Obovoid and clavate conidia of the aerial mycelium. FIG. 31 from BBA 69551, 32, 33 from BBA 69552. Scale bars = 25 μm .

terminati. Phialides in mycelio aero cylindricae, monopodialidace, aliquando polyphialidace, usque ad 30.0 μm longae et 2.5 μm latae. Conidia in mycelio aero obovoidea vel clavata, aliquando oblongo-ovalia; 0-septata: (5.0–)5.2–7.4–9.6(–13.8) \times 1.9–2.4–2.9(–4.0) μm . Verae chlamydosporae absentes. Holotypi origo geographica. Nigeria, in *Pennisetum typhoides*. Ex holotypo culturae. NRRL 13592, BBA 69552. FRC M-1166. CBS 417.97. IMI 375342. DAOM 225136.

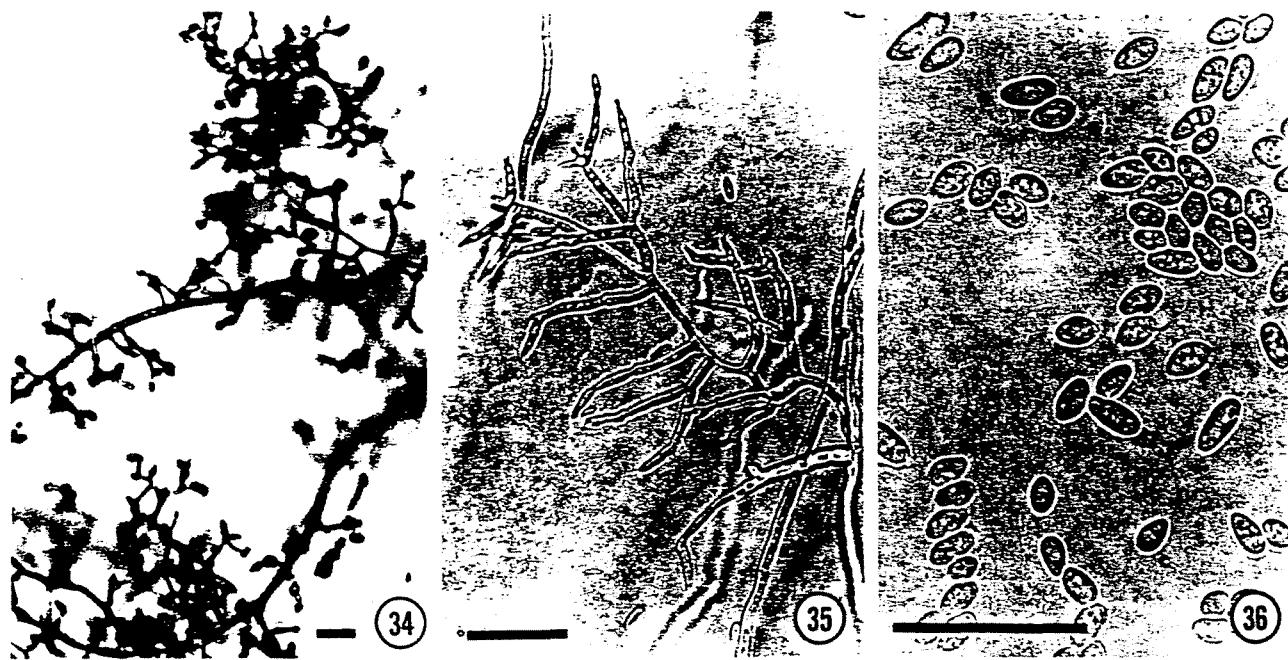
HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average mycelial growth rate of 4.4 mm/da at 20°C; colony margin entire. Aerial mycelium almost white; short, lanose to funiculose, also fluffy. Pigmentation in reverse grevish-orange to grey-violet with the center blackish-blue. Sclerotia absent. Sporulation starting early in the aerial mycelium, conidia aggregated in false heads and short to long chains; sporodochia not observed. Odor not perceptible. Conidiophores of the aerial mycelium, prostrate, sometimes identical with phialides, sometimes with one or two lateral branch(es), branches terminating mostly in 1 phialide. Phialides of the aerial conidiophores cylindrical, monopodialic, sometimes polyphialidic, up to 30.0 μm long and 2.5 μm wide. Conidia borne in the aerial mycelium obovoid to clavate, sometimes long-oval; 0-septate: (5.0–)5.2–7.4–9.6(–13.8) \times 1.9–2.4–2.9(–4.0) μm . True chlamydospores absent.

Isolates studied. NRRL 6022 = BBA 69551 = CBS 416.97 = MRC 1412, Nigeria, *Pennisetum typhoides*; NRRL 13592

= FRC M-1166 = BBA 69552 = CBS 417.97 = IMI 375342
= DAOM 225136 (*ex holotype*), Nigeria, *P. typhoides*.

Notes. As the epithet implies, *F. pseudonygamai* is morphologically very close to *F. nygamai* (Burgess and Trimboli, 1986), and our two isolates have been reported as *F. nygamai* in the literature (Marasas et al., 1988a, b; Nelson et al., 1992). Marasas et al. (1988a, b) noted morphological differences between isolates from *Pennisetum typhoides* (=*F. pseudonygamai*) and *F. nygamai* from *Sorghum bicolor*, but they concluded that all of these isolates were *F. nygamai*. Marasas et al. (1988b) reported that the phialides produced by NRRL 6022 *F. pseudonygamai* are shorter and the macroconidia are longer and narrower than those found in *F. nygamai*. In addition, we did not observe the formation of true chlamydospores in cultures of *F. pseudonygamai*, only a few swollen hyphal cells in chains. *Fusarium pseudonygamai* also produces slightly longer conidial chains in the aerial mycelium. According to our phylogenetic analysis, this species and *F. nygamai* are members of the African clade (O'Donnell et al., 1998). A survey of fumonisin B₁ production which included NRRL 13592 = FRC M-1166 as *F. nygamai* together with 14 other isolates from millet did not detect this toxin. However, authentic isolates of *F. nygamai* (e.g., NRRL 13488 = FRCM-1375 *ex holotype*) do produce fumonisin B₁ (Nelson et al., 1992).



Figs. 34-36. *Fusarium ramigenum*. 34. Aerial mycelium with branched, prostrate conidiophores producing conidia in false heads. 35. Polypodialidic conidiophore of the aerial mycelium branched at two levels. 36. Obovoid conidia of the aerial mycelium. FIGS. 34, 35 from BBA 68592, 36 from BBA 68593. Scale bars = 25 μm .

10. *Fusarium ramigenum* O'Donnell et Nirenberg.
sp. nov.

FIGS. 34-36

Coloniae in PDA quasi 3.5 mm per diem crescentes, 20 C. margine integro. Mycelium aerium albidum, lanosum usque funiculosum. Color in parte aversa aurantiaco-albus usque rubro-brunneus. Sclerotia absentia. Initium sporulationis in mycelio aero praecox, conidiis in relativis capitulis falsis parvis aggregatis cum illis capitulis aliorum speciem sectionis Liseolae comparatis: sporodochia absentia. Odor non perceptibilis. Condiophora in mycelio aero prostrata, fortiter ramosa, etiam sympodialiter proliferentia, rami plerumque in 1 vel 2 phialides terminati. Phialides conidiophorum in mycelio aero cylindricae, aliquae monopodialidicae, aliquae polyphidalidicae, usque ad 30.0 μm longae et ad 3.0 μm latae. Conidia in mycelio aero late obovoidea, plerumque 0-septata: (5.8-)5.9-6.7-7.5(-9.1) \times (2.0-)2.3-2.8-3.3(-3.8) μm . Chlamydospores absentes. Holotypi origo geographica. California, USA, in *Ficus carica*. Ex holotypo culturae. NRRL 25208, BBA 68592, CBS 418.97, IMI 375343, DAOM 225137.

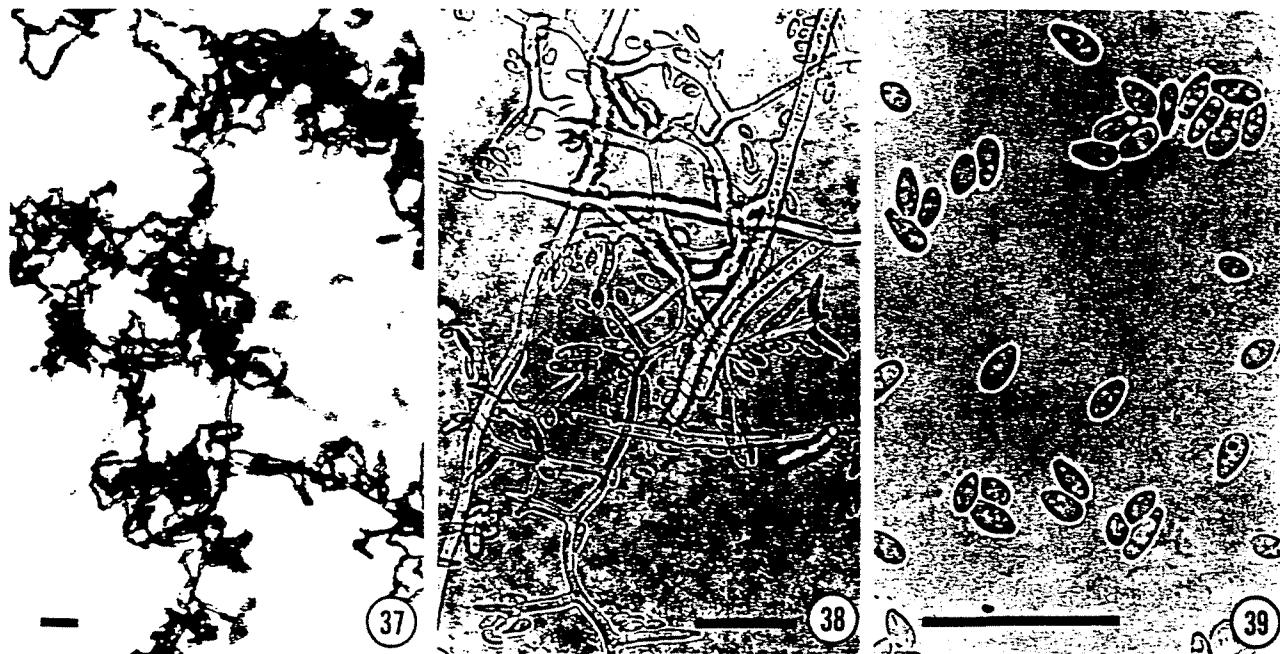
HOLOTYPE. Depositus in herb. B.

Colonies on PDA showing average mycelial growth rate of 3.5 mm/da at 20 C; colony margin entire. Aerial mycelium almost white to pinkish-white; lanose to funiculose. Pigmentation in reverse orange-white to reddish-brown. Sclerotia absent. Sporulation starting early in the aerial mycelium, conidia aggregating in relatively small false heads in contrast to those of other species in section *Liseola*; sporodochia absent. Odor not perceptible. Conidiophores of the aerial mycelium prostrate, branching extensively, branches

mostly terminating in 1 or 2 phialides, also proliferating sympodially. Phialides of aerial conidiophores cylindrical, some monopodialidic, some polyphidalidic, up to 30.0 μm long and 3.0 μm wide. Conidia borne on the aerial mycelium broadly obovoid, mostly 0-septate: (5.8-)5.9-6.7-7.5(-9.1) \times (2.0-)2.3-2.8-3.3(-3.8) μm . Chlamydospores absent.

Isolates studied. NRRL 25208 = BBA 68592 = CBS 418.97 = IMI 375343 = Michailides F50 = DAOM 225137 (*ex holotype*), CA, USA, *Ficus carica*; NRRL 25212 = BBA 68493 = CBS 421.97 = Michailides F62, CA, USA, *F. carica*; NRRL 25341 = Michailides F21, CA, USA, *F. carica*; NRRL 25685 = BBA 69864 = Michailides F61, CA, USA.

Notes. The epithet refers to the highly branched conidiophores of the aerial mycelium. Macroscopic growth of *F. ramigenum* is very similar to *F. lactis*, but *F. lactis* produces short, zigzaglike chains of conidia whereas *F. ramigenum* does not under the growth conditions used. *Fusarium ramigenum* is also able to produce short chains when cultivated in a 12 hour alternating light-dark-cycle. Different host preferences appear to be exhibited by these two fig pathogens. While only one of the four isolates of *F. ramigenum* was isolated from calimyrna figs, all six isolates of *F. lactis* were obtained from this host (reported as *F. moniliforme* Sheldon; Subbarao and Michailides, 1993; Michailides et al., 1996). *Fusarium ramigenum* NRRL 25208, NRRL 25212, and NRRL 25685 were isolated from inedible wild caprifigs and Black Mission figs, respectively. According to our biogeograph-



Figs. 37-39. *Fusarium lactis* from BBA 68590. 37. Aerial mycelium with branched, prostrate conidiophores producing conidia in zigzaglike chains. 38. Branched polyphialidic conidiophores of the aerial mycelium. 39. Obovoid conidia of the aerial mycelium. Scale bars = 25 μm .

ic hypothesis (O'Donnell et al., 1998). *F. ramigenum* and *F. lactis* share the same area of endemism as their African host, *Ficus carica*.

11. *Fusarium bulbicola* Nirenberg et O'Donnell, nom. nov.

= F. sacchari (Butler) W. Gams var. *elongatum* Nirenberg.
Mitt. Biol. Bundesanst. Land-Forstw. Berlin-Dahlem 169: 59. 1976, non *F. elongatum* Reinking, 1934.

Colonies on PDA showing average mycelial growth rate of 5.7 mm/da at 20°C; colony margin entire. Aerial mycelium almost white, later tinged ruby by the substrate; short, hairy to lanose. Pigmentation in reverse dark ruby. Sclerotia absent. Sporulation starting early in the aerial mycelium aggregating in false heads; sporodochia formed after 14 da under black light. Odor not perceptible. Conidiophores of the aerial mycelium erect, branched, branches terminating mostly in 1 or 2 cylindrical phialides; phialides to 30.0 μm long and 3.0 μm wide. Sporodochial conidiophores vertically branched. Conidiophores in the aerial mycelium mono- and polyphialidic; sporodochial phialides flask-shaped and monopodial. Conidia borne on the aerial mycelium long-oval to allantoid, mostly 0-septate, measuring: (7.9-)8.6-9.9-11.2(-12.6) \times (2.1-)2.3-2.7-3.1(-3.4) μm . Conidia borne in sporodochia long and slender, falcate with a slightly elongate apical cell and a footlike basal cell, mostly 3- to 5-septate; 3-septate: (48.0-)51.2-57.9-64.7(-72.0) \times (3.2-)3.4-3.5-3.6(-3.8) μm . Chlamydospores absent. Holotype geographic origin. Netherlands, on *Nerine bowdenii*. Ex holotype cultures. NRRL 13618, BBA 63628, CBS 220.76, IMI 375322, DAOM 225114.

HOLOTYPE deposited in IMI (202877).

Isolates studied. NRRL 13600 = FRC M-1354 = BBA 63620, Germany, *Haemanthus* sp.; NRRL 13618 = CBS 220.76 = BBA 63628 = IMI 375322 = DAOM 225114 (*ex holotype*), Netherlands, *Nerine bowdenii*; NRRL 22947 = CBS 245.59 = BBA 63620, Germany, *Haemanthus* sp.; NRRL 25176 = BBA 63622, Germany, *Nerine bowdenii*; BBA 62271, Germany, *Nerine bowdenii*.

Notes. The epithet means bulb-inhabiting. The long slender sporodochial conidia of *F. bulbicola* resemble those of *F. begoniae*, but the conidiophores in *F. bulbicola* are typically erect in contrast to *F. begoniae* where they are prostrate and typically consist of single phialides. Our biogeographic hypothesis indicates that both of these fusaria are American species (O'Donnell et al., 1998).

12. *Fusarium lactis* Pirotta & Riboni, *Arch Lab. Bot. Crittogram. Pavia* 2: 316. 1879. FIGS. 37-39

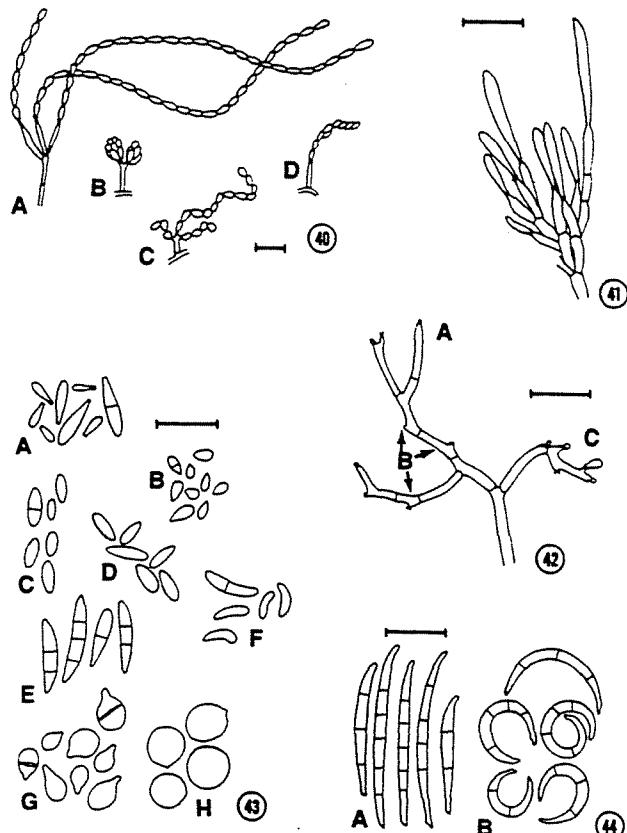
Because the type of *F. lactis* (Pirotta and Riboni, 1879) cannot be found in PAV or PAD (Herbarium Saccardo), a neotype is selected for this species and placed in B. It represents a dried SNA culture of BBA 68590. Neotype geographic origin. CA, USA, on *Ficus carica*. Ex neotype cultures. NRRL 25200, BBA 68590, CBS 411.97, IMI 375351, DAOM 225145.

NEOTYPE. Deposited in B.

Isolates studied. NRRL 25200 = BBA 68590 = Michailides

F41 = CBS 411.97 = IMI 375351 = DAOM 2254145 (*ex* neotype), CA, USA, *Ficus carica*; NRRL 25334 = BBA 69865 = Michailides F1, CA, USA, *F. carica*; NRRL 25338 = Michailides F13 = BBA 68591 = CBS 420.97, CA, USA, *F. carica*; NRRL 25339 = Michailides F15 = BBA 69866, CA, USA, *F. carica*; NRRL 25340 = Michailides F18 = BBA 69867, CA, USA, *F. carica*; NRRL 25344 = Michailides F64 = BBA 69868, CA, USA, *F. carica*.

Notes. The epithet refers to the milk substrate from which this species was originally isolated as a contaminant associated with other fungi. Wollenweber (*Fusaria autographice delineata* 1155, 1156, 1935) obviously correctly identified isolates from figs as *F. lactis*, as the species can occur both on fruit as a pathogen and on milk products as a contaminant. Gerlach and Nirenberg (1982) discussed *F. lactis* and regarded the name as a nomen confusum, but the only strains from figs available for study were *F. proliferatum*. If they had had all four species now known to occur on figs, *F. verticillioides* (Sacc.) Nirenberg (produces clavate conidia mainly in long, linear, crowded chains from monophialides in the dark), *F. proliferatum* (produces clavate conidia mainly in long, linear, crowded chains from mono- and polyphialides in the dark), *F. ramigenum* (produces obovoid conidia only in false heads, mainly on polyphialides in the dark) and *F. lactis*, (produces obovoid conidia in zig-zaglike, short to medium, crowded chains, mainly on polyphialides) their conclusions would have been different. The isolates from figs that form short to medium length, zigzaglike chains match the description and drawings (Fig. 40C) of Wollenweber and Reincking (1935) and unpublished ones that exist in the mycotheque in Berlin. *Fusarium lactis* appears to exhibit a strong host preference because all six strains were isolated from cultivated Calimyrna figs (Subbarao and Michailides, 1993; Michailides et al., 1996) and none from milk products. Marasas et al. (1995) examined mycotoxins produced by ten of Subbarao's and Michailides' (1993) fig isolates grown on autoclaved corn. In this study, Marasas et al. (1995) re-



Figs. 40–44. Conidial and conidiophore features. 40. Arrangement of conidia on conidiophores of the aerial mycelium: A, linear chains; B, false heads; C, zigzaglike chains; D, false chain. 41. Sporodochial conidiophores. 42. Types of conidiogenous loci on conidiophores of the aerial mycelium: A, monophialide; B, intercalary phialides; C, polyphialides. 43. Conidial shapes: A, clavate; B, obovoid; C, oval; D, obovoid to elliptical; E, fusiform; F, allantoid; G, pyriform; H, napiform. 44. Sporodochial conidia: A, falcate; B, annulate. Scale bars = 20 µm.

ported that isolates of *F. proliferatum* (Matsushima) Nirenberg with atypically short chains (*=F. lactis*) that were weakly virulent produced high levels of moniliformin but no fumonisin.

KEY TO DESCRIBED *FUSARIUM* SPECIES OF THE *GIBBERELLA FUJIKUROI* COMPLEX AND RELATED SPECIES

1. 0- to 1-septate oval conidia without foot-cell produced on the agar surface, never in the aerial mycelium *F. bactridioides*
1. 0- to 5-septate conidia without foot-cell produced in the aerial mycelium 2
 2. Chlamydospores produced within 14 da in the dark 3
 2. Chlamydospores not produced within 14 da in the dark 9
 3. Chlamydospores mostly lateral or terminal, borne singly or in pairs, rarely in clusters; polyphialides absent section *Elegans*²
 3. Chlamydospores mostly intercalary, typically borne in chains or clusters; polyphialides sometimes present 4
 4. Conidia forming chains and false heads in the aerial mycelium 5
 4. Conidia not forming chains in the aerial mycelium 7

² The infragenetic grouping section *Elegans* is not monophyletic as currently circumscribed (O'Donnell et al., 1998).

5. Some pyriform conidia produced	6
5. No pyriform conidia produced	<i>F. nygamai</i>
6. Clavate and pyriform conidia produced in long linear chains (>30 conidia) on monopodialides	<i>F. napiiforme</i>
6. Obovoid and pyriform conidia produced, sometimes in short false chains (<15 conidia) on mono- and polyphialides	<i>F. pseudoanthophilum</i>
7. Conidiophores often branched, each branch often ending with polyphialides	<i>F. pseudoanthophilum</i>
7. Conidiophores rarely branched, rarely forming polyphialides	8
8. Sporodochial conidia mostly 3-septate with an uncinate apical and basal cell; never producing pyriform conidia in the aerial mycelium	<i>F. udum</i>
8. Sporodochial conidia mostly 3-septate with an acute apical cell; never producing pyriform conidia in the aerial mycelium	1. <i>F. acutatum</i>
8. Sporodochial conidia mostly 5-septate with a slightly beaked apical cell; occasionally producing pyriform conidia in the aerial mycelium	<i>F. dlamini</i>
9. Coiled sterile hyphae formed in and on the agar	10
9. Coiled sterile hyphae not formed	11
10. Conidia aggregated in false heads, never in chains	3. <i>F. circinatum</i>
10. Conidia aggregated in false heads and in short false chains (<15 conidia), when cultivated under continuous black light	8. <i>F. pseudocircinatum</i>
11. Conidia adhering in chains and false heads	12
11. Conidia adhering only in false heads, chains absent	24
12. Conidia only borne on monopodialides	13
12. Conidia borne on mono- and polyphialides	14
13. Conidia borne on conidiophores that often terminate verticillately with 3 phialides; cosmopolitan on numerous plant hosts, especially cereals	<i>F. verticilliodes</i> (Sacc.) Nirenberg
13. Conidia borne on conidiophores that usually terminate verticillately with 4 phialides; cultures typically produce slimy dark violet plaques on PDA within 5 da; pathogenic to <i>Sorghum</i> spp.	<i>F. thapsinum</i>
14. Pyriform and clavate conidia produced in chains	15
14. Pyriform conidia not produced	16
15. Polyphialides frequent; sporodochia produced	<i>F. proliferatum</i> ³
15. Polyphialides rare; sporodochia not produced	<i>F. nisikadai</i> ⁴
16. Globose conidia produced singly or in botryose clusters	<i>F. globosum</i>
16. Globose conidia not produced	17
17. Polyphialides rare; sympodially proliferating conidiophores common	18
17. Polyphialides usually abundant; sympodially proliferating conidiophores rare	19
18. Clavate conidia mostly 0–3-septate; sporodochial conidia up to 7-septate; on <i>Phyllostachys</i> and <i>Triticum</i>	<i>F. nisikadai</i> ⁴
18. Clavate conidia mostly 0-septate, rarely 1-septate; sporodochial conidia typically 3–5-septate; causing gibberellin-induced bakanae disease on <i>Oryza sativa</i>	<i>F. fujikuroi</i> Nirenberg
19. Conidia adhering in short (<15 conidia) to medium length chains (15–30 conidia)	20
19. Conidia adhering in long chains (>30 conidia)	23
20. Conidial chains produced under any light condition	21
20. Conidial chains produced either in the dark or under black light	22
21. Conidial chains zigzaglike, of short (<15 conidia) or medium length (15–30 conidia); causing fruit endosepsis in <i>Ficus carica</i>	12. <i>F. lactis</i>
21. Conidial chains linear, of short (<15 conidia) or medium length (15–30 conidia); pathogenic to <i>Pennisetum typhoides</i>	9. <i>F. pseudonygamai</i>
22. Short (< 15 conidia) linear conidial chains formed abundantly only in the dark, pathogenic to <i>Sansevieria</i> , <i>Gasteria</i> and <i>Dracaena</i> spp.	7. <i>F. phyllophilum</i>
22. Short (<15 conidia) false conidial chains formed only under continuous black light	<i>F. brevicutenulatum</i>
23. Sporodochial conidia almost straight	<i>F. proliferatum</i> ³
23. Sporodochial conidia strongly recurved, some ring-shaped	<i>F. annulatum</i> Bugnicourt ³
24. Conidiophores mainly erect, branched	25
24. Conidiophores mainly prostrate, mostly branched	28
25. Pyriform conidia produced	<i>F. anthophilum</i> (A. Braun) Wollenw.
25. Pyriform conidia not produced	26
26. Conidia oval to fusoid, mostly 0–3-septate; pathogenic to <i>Zea mays</i>	<i>F. subglutinans</i>
26. Conidia obovoid or oval, mostly 0-septate	27

³ *F. proliferatum* is indistinguishable from *F. annulatum* (Bugnicourt, 1952) with any molecular sequences tested so far.

⁴ *F. nisikadai* (Nirenberg and Aoki, 1997) is not a member of the *G. fujikuroi* complex (O'Donnell et al., 1998).

27. 0-septate conidia mostly obovoid; pathogenic to *Ananas comosus* 6. *F. guttiforme*
 27. 0-septate conidia mostly oval; pathogenic to *Nerine*, *Vallota* and *Haemanthus* flower bulbs 11. *F. bulbicola*
 28. Conidiophores branched at two levels (FIG. 35); pathogenic to *Ficus carica* 10. *F. ramigenum*
 28. Conidiophores branched at one level (FIG. 7) 29
 29. Sporodochial conidia present, strongly recurved, some ring-shaped; pathogenic to *Succisa pratensis*
 *F. succisae* (Schröter) Sacc.
 29. Sporodochial conidia absent, or when present almost straight 30
 30. Pyriform conidia produced; pathogenic to *Saccharum officinarum* *F. sacchari* (Butl.) W. Gams
 30. Pyriform conidia not produced 31
 31. Conidiogenous openings protruding at right angles, denticulate; pathogenic to *Ipomoea batatas* 5. *F. denticulatum*
 31. Not as above 32
 32. Sporodochia not formed in wild-type cultures; pathogenic to *Saccharum officinarum*, causing pokkah boeng
 disease *F. sacchari*
 32. Sporodochia formed in wild-type cultures 33
 33. Sporodochial conidia mostly 3–5 septate; on *Musa sapientum* 4. *F. concentricum*
 33. Sporodochial conidia mostly 3-septate; pathogenic to *Begonia* spp. 2. *F. begoniae*

DISCUSSION

A synopsis of differentiating morphological features of species of the *G. fujikuroi* complex is given in TABLE II and a key to the described species is provided. Because morphological expressions are not understood equally, the most common ones used for describing species of the genus *Fusarium* (Wollenweber and Reinking, 1935; Toussoun and Nelson, 1968; Booth, 1971; Gerlach and Nirenberg, 1982; Burgess et al., 1988) and especially of the *G. fujikuroi* complex (*Liseola* section) are drawn in FIGS. 40-44 and/or explained as follows: *aerial mycelium*—hyphae including vegetative fruiting structures such as conidiophores growing above the substrate surface; *allantoid*—conidia slightly curved, almost rounded at both ends, only produced in false heads (FIG. 43F); *annulate*—conidia with strongly curved apical and basal cells which often almost touch each other (FIG. 44B); *chlamydospores*—thick-walled resting asexual cells, globose, subglobose to oval, smooth, of similar size, between 6.0-12.0 μm ; *clavate*—conidia club-shaped with a rounded distal end and a truncate basal end, typically produced in long linear chains (FIG. 43A); *conidia of the aerial mycelium*—of different shapes, sometimes apiculate, but never foot-shaped (FIG. 43A-H); *conidiophores of the aerial mycelium*—for these important diagnostic features in the characterization of *Fusarium* species see FIGS. 40 and 42; *erect conidiophores*—conidiophores arising directly from the substrate hyphae; *falcate*—conidia slightly sickle-shaped (FIG. 44A); *false chains*—chains in which the conidia seldom cohere at their ends, but are mostly displaced at their sides (FIG. 40D); *false head*—spherical aggregation of conidia at the opening of a phialide, which may be dry or wet; this expression is in contrast to "true head" which refers to the sporangia of the *Zygomycetes* (FIG. 40B); *fusiform*—conidia straight, pointed at both ends, produced only in

false heads (FIG. 43E); *linear chains*—chains in which the conidia adhere to each other at their basal and distal ends in one line which may be straight or sinuate (FIG. 40A); *monophialide*—phialide with one conidiogenous opening (FIG. 42A); *napiform*—conidia almost round with a tiny apiculum (FIG. 43 H); *obovoid*—conidia with a pointed basal end and a rounded distal end, forming zigzaglike chains or heads (FIG. 43B, D); *oval*—conidia oblong, widest in the middle, symmetric, slightly rounded at both ends (FIG. 43C); *polyphialide*—phialide with more than one conidiogenous opening (FIG. 42C); *proliferating conidiophores*—conidiophores with intercalary phialides often created by sympodially proliferating growth of the conidiophore (FIG. 42B); *prostrate conidiophores*—conidiophores arising from hyphae that grow horizontally above the substrate surface; *pyriform*—conidia pear-shaped, produced in chains or false heads (FIG. 43G); *sclerotium*—consisting throughout of plectenchymatious tissue, without a special outer layer of darker, thick-walled cells; *single phialide*—one phialide, size range between $1.0-40.0 \times 1.8-3.0 \mu\text{m}$ (often peglike in section *Liseola*, tiny phialides are produced on hyphae that grow just above the agar surface), therefore only the longest measurements are given, using the expression “up to” (FIG. 40B, C, D); *sporodochial conidia*—conidia produced in a conidioma, mostly falcate with a foot-shaped basal cell (FIG. 44A, B); *sporodochial conidiophores*—produced in a conidioma with very uniform phialides, therefore not useful for characterization of *Fusarium* species, branching densely, terminating in one to four monophialides, which measure between $9.5-26.0 \times 1.8-4.0 \mu\text{m}$ (FIG. 41); *uncinate*—conidia with apical and basal cell hooked in the same direction, middle section of the conidium mostly straight; *wild-type culture*—isolates made on a low nutrition medium that exhibit healthy phenotypic characters; they need not

TABLE II. Synopsis of morphological features of the 29 described *Fusarium* species of the *Gibberella fujikuroi* complex

Species	Shape of conidia in the aerial mycelium				Conidial arrangement			Conidiophores of the aerial mycelium			Sporodochial conidia	Resting cells	Other characters	
	Pyri-form	Globose	Clavate	Obovoid	Oval to allan-toid and/or fusoid	Short chains (<15 conidia)	Medium to long chains (>15 conidia)	False heads only (chains absent)	None in aerial mycelium	Mostly un-branched	Mono-phialidic only			
<i>F. acutatum</i>					+			+						+
<i>F. annulatum</i>			+					+					+	
<i>F. anthophilum</i>	+					+		+					+	
<i>F. bactridioides</i>						+					+			- ^a
<i>F. begoniae</i>					+	+		+						
<i>F. brevicatenulatum</i>			(+) ^b			+					(+)			
<i>F. bulbicola</i>						+					+			
<i>F. circinatum</i>					+	(+)					+			+
<i>F. concentricum</i>					+	+					(+)			
<i>F. denticulatum</i>						+					(+)			
<i>F. dlamini</i>	+					+					+			+
<i>F. fujikuroi</i>			+					+						
<i>F. globosum</i>		+	(+)		+		+	(+)						
<i>F. guttiforme</i>						+					+			
<i>F. lactis</i>						+		(+)						
<i>F. napiforme</i>	+		+	(+)				+				+		+
<i>F. nygamai</i>		(+)			+		+							+
<i>F. phyllophilum</i>			+				+				+			
<i>F. proliferatum</i>	(+)		+					+						
<i>F. pseudoanthophilum</i>	(+)		+		(+)	(+)			(+)		(+)			+
<i>F. pseudocircinatum</i>						+	+							+ ^c
<i>F. pseudonygamai</i>		(+)			+	(+)	+	(+)			+			- ^d
<i>F. ramigenum</i>					+						+			
<i>F. sacchari</i>	(+)					+					+			
<i>F. subglutinans</i>						+					+			
<i>F. succisae</i>						+					+			+
<i>F. thapsinum</i>		+	+				+							
<i>F. udum</i>						+					+			
<i>F. verticilliodes</i>		+					+				+			+

^a According to Wollenweber and Reinking (1935) *F. bactridioides* produces chlamydospores but they were not observed in the ex-type culture.^b (+) indicates that this character is not present in all isolates of this species.^c Marasas et al. (1988b) reported that this species produces chlamydospores (as *F. nygamai*), but they were not observed in the cultures we studied.

to be fresh isolates, since strains can be still in this state if they are preserved properly after isolation; *zigzaglike chains*—chains in which the distal end of one conidium is connected to the basal end of another in an angular arrangement (FIG. 40C).

The present systematic account of the *G. fujikuroi* complex together with the concurrent publication of two additional species (*F. brevicatenulatum* Nirenberg et al., and *F. pseudoanthophilum* Nirenberg et al., Nirenberg et al., 1998); *F. globosum* Rheeder et al. (1996) and *F. thapsinum* (Klittich et al., 1997) brings the number of described species within this lineage to 29. Molecular systematic data indicate the existence of at least eight additional phylogenetically distinct species within this lineage (O'Donnell et al., 1998; O'Donnell and Nirenberg, unpubl.), but additional strains and studies are required before they can be described formally.

The species boundaries identified in the present systematic treatment should greatly increase the accurate prediction of host range, mating compatibility, and mycotoxin potential of each species. Given that a phylogenetically-based classification offers the greatest predictive value (O'Donnell, 1996), we anticipate that molecular phylogenetics will play an essential role in resolving the natural relationships of all species of *Fusarium*, a genus noted for its extreme morphological crypsis.

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